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A RETURN ON INVESTMENT MODEL FOR AIR FORCE TECHNOLOGY TRANSFER

THESIS

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AFIT/GCA/LAS/98S-5

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

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THESIS

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Abstract

Air Force policy states the fundamental reason for participating in technology transfer is to maximize the return on investment (ROI) on research and development (R&D) funds. Public law dictates that federal agencies, including the Air Force, are to spend no less than 0.5% of their overall R&D budget in the pursuit of technology transfer. However, there is currently no ROI model available to the decision-maker in the evaluation of alternative transfer opportunities. This research effort develops a model that measures the ROI of individual cooperative research and development agreements (CRDAs) on the basis of the objective and subjective benefits amassed. The model results assist the decision-maker by providing a relative ranking of each transfer opportunity in comparison to one another. A sensitivity analysis method and results are included which identify definite regions of alternate "optimal" choices depending on the weight given to objective and subjective benefits. Consequently, the decision-maker is provided with a flexible model for use in maximizing ROI, the Air Force's goal for technology transfer.

A RETURN ON INVESTMENT MODEL

FOR AIR FORCE TECHNOLOGY TRANSFER

I. Introduction

Background

For a country to prosper over the long run, its economy must grow. According to President Clinton and Vice President Gore, "technology is the engine of economic growth" (Clinton and Gore, 1993:7). Why is technology so important? Technology improves individual quality of life and promotes a nation's economic strength (Clinton and Gore, 1993:2). Without this engine, the country's economy and individual quality of life cannot flourish. The United States is a case in point, as two-thirds of its productivity growth since the Great Depression is directly attributable to technological advancement (Clinton and Gore, 1993:7).

Unfortunately, the U.S. has lost some of the large technological edge it once enjoyed (Winebrake, 1992:54). This can be attributed to several factors. First, the fall of the Berlin Wall and the end of the Cold War have required the U.S. to redirect a technology strategy which had been unchanged in over forty years. Second, the governments of other countries are actively pursuing technological strategies synergistically linking government to private industry. Finally, in conjunction with the previous factor, the transfer of technology from United States government to its private sector is lacking.

Fall of the Berlin Wall/End of Cold War

The fall of the Berlin Wall and the end of the Cold War have had a large impact on the United States' approach to technology development. During the Cold War, the United States government's role in the development of technology was limited to the basic sciences and mission-oriented R&D (Clinton and Gore, 1993:1). The Department of Defense (DoD), the National Aeronautical and Space Administration (NASA), and other agency mission-oriented research focused on combating Eastern Europe and the former Soviet Union (Clinton and Gore, 1993:1). However, change is required if the United States is to regain its former position of strength as changing times require changing policy. In accordance, the President and Vice President outline the new role of government in the development of technology in their document entitled, *Technology for America's Economic Growth, A New Direction to Build Economic Strength*. The primary tenets of the new direction are:

- Strengthening America's industrial competitiveness and creating jobs;
- Creating a business environment where technical innovation can flourish and where investment is attracted to new ideas;
- Ensuring the coordinated management of technology all across the government;
- Forging a closer working partnership among industry, federal and state governments, workers, and universities;

- Redirecting the focus of our national efforts toward technologies crucial to today's businesses and a growing economy, such as information and communication, flexible manufacturing, and environmental technologies; and,
- Reaffirming a commitment to basic science, the foundation on which all technical progress is ultimately built.

The overall thrust is summed up by saying the United States must: (1) refocus technology development to those items needed today (in the post Berlin Wall/ Cold War era); (2) establish relationships between government agencies, as well as between government and industry; and (3) remain committed to basic science, the foundation of technological development in the future.

International Technology Strategies

Much of the United States' decline in technological superiority stands in stark contrast to the approach to technological development taken by other countries. As highlighted above, the United States is in the midst of changing its policy to one which other countries have already implemented. The governments of European countries have been enabling many companies to prosper via government-funded research and development (R&D) for years (Scott, 1993:64). Data from 1992 indicate that the number of Technology Application/Education Centers in West Germany was over fifty, Japan had over one hundred and seventy, while the United States had less than ten (Strategic Development Staff, 1992:1, 8). This is especially impressive in West Germany, a country going through so many changes after the fall of the Berlin Wall.

France, Germany, and Italy are specifically highlighted as countries in which federal laboratories and private industry routinely share information (Scott, 1993:64). This sharing results in the development of commercial products (Scott, 1993:64). These countries and their private industries recognize that technology transfer has the potential to be a "win-win" situation.

United States Technology Strategy

As illustrated by other countries' success and the new policy presented by the United States' President and Vice President, the transfer of technology from government to industry is vital to a country's economic success. The United States has approached this process passively in the past, hoping that technology developed for space and national defense would "leak" over to the private sector (Clinton and Gore, 1993:7). However, today there is an active means in place to accomplish this process called technology transfer. Technology transfer is defined by the Air Force Materiel Command (AFMC) Technology Transfer handbook (1995:O-5) as:

> A process by which facilities, equipment, or other resources relating to scientific or technological developments of a federal laboratory are provided or disclosed by any means to another industrial organization, including a corporation, partnership, limited partnership, or industrial development organization; public or private foundation; nonprofit organization, including a university, or other person to enhance or promote technological or industrial innovation for a commercial or public purpose.

The current tenor of technology transfer is to be more proactive, to actively seek and establish relationships between government and private industry, in effect to emulate those countries who have shrunk the technology gap that once existed between them and the United States.

Technology transfer's importance increases with each passing year. Why? Because private industry is "underinvesting in R&D" due to a perception that it is too risky (Winebrake, 1992:54). In fact, some leading companies have determined that R&D should be considered a sunk cost, not an investment with the potential to bring positive returns (Willett, 1992:96). However, a "fair sharing" of the risk (partly via cost-sharing) between government and private industry (as illustrated by European countries) promotes economic growth and makes strides in eliminating this perception concerning R&D money (Clinton and Gore, 1993:5). Cost-sharing brings the commitment of both parties to the transfer because investment returns are only experienced when the project works (Winebrake, 1992:59).

Technology transfer is important, too, because those receiving federal R&D dollars must realize where the money originated. Just as the corporate investor has a right to a return on his/her investment, so does the American taxpayer. Baron found that the United States government does not perform cost-benefit analysis to determine whether research entered into will be profitable (Baron, 1990:38). Therefore, taxpayer return on investment is not addressed, and the federal government is not fulfilling its responsibility in this regard. Taxpayers provide support to over 700 laboratories and pay the salaries of nearly one-sixth of the nation's scientists and engineers (100,000 total). However, less than 5% of the 30,000 patents granted to the federal government were eventually turned into commercial items (AFMC Handbook, 1995:A-1). Mission-related projects are being accomplished, but laboratories have the ability to create additional benefits via technology transfer. This capability must be exploited for two reasons: (1) if not, the technological

position of the United States will continue to erode; and (2) the perception is growing that the country is not receiving adequate returns on its R&D investment (Carr, 1992A:8).

Relevancy

There is much regulation and guidance addressing technology transfer. So why has technology transfer been so limited? The lack of a measurement tool is one critical factor. There exists no device to help determine which technology transfer opportunities should be pursued. There is no dispute that technology transfer contains benefits and costs. However, politicians see benefits, industry sees benefits, but R&D managers (those left to implement technology transfer) only see costs. The reason for the R&D manager's view is that he or she is given a specific amount of money to perform his or her mission for the year. In order to perform technology transfer, the resources needed (including money and manpower) must be taken from that "mission" budget. Without the ability to determine the profitability of a specific technology transfer, R&D managers perform what they get paid for (the mission) and participate in technology transfer at the minimum funding level dictated by law (0.5% of the overall R&D budget) (AFMC Handbook, 1995:A-2).

While technology transfer costs apply to federal laboratories, there are potential benefits, too. R&D managers realize there are potential benefits such as royalties, rental fees, etc. that can add to his or her "pot of money." Once again, however, the lack of a measurement mechanism does not allow these potential benefits to be weighed versus potential costs. This is especially disheartening when one considers the AFMC Technology Transfer handbook states, "The Air Force participates in DT^2 (domestic technology transfer) to maximize its return on investment in RDT&E" (AFMC Handbook,

1995:A-5). This statement suggests return on investment is the purpose for conducting technology transfer, but the Air Force and R&D managers currently have no measurement tool in place to determine return on investment. Clearly, this issue must be addressed.

The R&D manager of each federal laboratory is in a compromising situation. On the one hand, directorates and regulations require managers to foster relationships with private industry through technology transfer. On the other hand, additional funds are not provided to pay for the resources required by technology transfer. In a way, just as the individual investor must make educated guesses as to where to invest money, the R&D manager must do the same. Presently, though, there is not a tool in existence that gives the R&D manager the ability to decide which technology transfer situations to enter.

The purpose of this research is to develop a return on investment (ROI) model for potential usage by those holding the R&D "purse strings" at the laboratory level in determining which technology transfers to pursue. This model will measure return on investment, a step that is necessary to achieve the Air Force's purpose for being in technology transfer in the first place: to maximize RDT&E return on investment. One cannot maximize return on investment if it cannot be measured. This research addresses this problem.

Research Objectives

The research objectives of this thesis are related to the simple question, "Which technology transfer opportunities should be entered into?" In order to answer this question, this research effort will evaluate past technology transfer performance and also

present a model for predicting TT performance. More specifically, the research objectives are:

A. **Propose a ROI model to be used by Air Force decision makers in performing Technology Transfer;**

B. **Evaluate the Return on Investment (ROI) of past Technology Transfers;**

C. **Perform Sensitivity Analysis on Technology Transfers when some inputs are uncertain.**

Thesis Overview

Chapter II provides an in-depth review of research concerning technology transfer and return on investment models. Chapter III contains the methodology of this research effort. A study will be conducted utilizing information collected from past Air Force technology transfers. In Chapter IV, the data collected on previous Air Force technology transfers will be analyzed according to a ROI model. The research will conclude in Chapter V with a discussion of results, conclusions drawn, and areas of potential follow-on research.

II. Literature Review

Introduction

The federal government was expected to spend $62.2 billion on R&D in 1997, more than half the total ($120.5 billion) expected to be spent by all of private industry (Studt and Duga, 1997:2). According to Duga, both the government and private industry have evolved from a "just in case" to a "just in time" approach concerning technology development (Duga, 1998:4). "Just in case" R&D spending (1960's – 1990), was highly focused on attempting to gather basic knowledge; "just in time" R&D spending (1990 – present) is focused on garnering technology based upon availability, regardless the supplier (Duga, 1998:4). With this current situation and the capabilities of the federal laboratory system, there is much opportunity for government and industry cooperation in the development of technology. However, 84% of private industry is expected to contract out their R&D, with only 4% directed toward federal laboratories. This can be partially attributed to the fact that federal laboratory R&D managers are hesitant to enter into technology transfer. Though current directives require proactive measures, R&D managers (just like the rest of the Department of Defense) realize that the mission comes first. If actions not directly related to the mission cannot be measured as to their impact on funding and manpower usage, they will not be pursued.

President Clinton and Vice President Gore's 1993 directive is not the only guidance associated with technology transfer. In fact, it is only a small part of a long procession of regulations, directives, and instructions which are presented in this chapter. The further purpose of this chapter is to address past research on the topics of technology transfer and

return on investment (ROI). Much research has been done on the topics of technology transfer and ROI; however, the two have not been linked successfully. An appropriate connection of the two topics will help overcome the shortcomings currently existing in technology transfer evaluation and participation.

Technology Transfer Guidance

Technology transfer is not a new idea. Its roots go back at least as far as 1956 when the Army-Navy Instrument Program (ANIP) provided the fundamentals needed for the development of military and civilian products such as solid-state computers, microcircuitry, and the field of human factors (Scott, 1992:64). However, the stream of laws and regulations began in 1980.

Technology transfer regulations were developed in hopes of optimizing the use of federal laboratories, their 100,000 scientists and engineers, and the $18 billion spent on R&D at the time (AFMC Handbook, 1995:A-1). The University and Small Business Patent Procedure Act (also known as the Bayh-Dole Act of 1980) attempted to increase the use of government technology by giving non-profit organizations and small businesses the ability to retain patents for technologies developed via government funds (AFMC Handbook, 1995:A-1). Provisions of the Bayh-Dole Act of 1980 were extended to all government contracts by Executive Order in 1983.

The Bayh-Dole Act of 1980 was followed by the Stevenson-Wydler Technology Innovation Act of 1980. This Act requires the government to ensure "… full use of the results of the nation's federal investment in research and development" (AFMC Handbook, 1995:A-2). An additional provision of the Act includes the establishment of

Offices of Research and Technology Applications (ORTAs), whose purpose is to disseminate information and help transfer technology from the laboratory to the public and private sectors (AFMC Handbook, 1995:O-3). The Act requires each federal agency to spend no less than 0.5% of its R&D budget on technology transfer-related activities (AFMC Handbook, 1995:A-2). The Act also mandates, where appropriate, the encouragement of the exchange of scientific and technical people among academia, industry, and federal laboratories, something that is acknowledged to have never been fully implemented (AFMC Handbook, 1995:A-2).

The subsequent piece of legislation was the Federal Technology Transfer Act of 1986 (FTTA of 1986). This Act is an amendment to the Stevenson-Wydler Technology Innovation Act (AFMC Handbook, 1995:A-2). The key provisions are as follows:

A. Agency and laboratory directors have latitude to enter into Cooperative Research & Development Agreements (CRDAs), and to negotiate patent licenses.

B. It permits royalty income from patent licensing and assignment of at least 15% of the royalties to the inventor.

C. Technology transfer is made a job requirement of every federal laboratory scientist and engineer.

D. ORTA involvement in laboratory management development programs is increased.

E. It provides a home for the Federal Laboratory Consortium (FLC), a group of 400 federal laboratories from 11 separate government agencies.

As one can see, an overarching theme of this act is to provide incentive for laboratory personnel to participate in technology transfer.

Several other pieces of legislation have facilitated technology transfer. Executive Order 12591, Facilitating Access to Science and Technology, became effective April 10,

1987 (AFMC Handbook, 1995:A-4). It reiterates certain provisions of the FTTA Act of 1986, such as mandating heads of executive departments and agencies to promote CRDAs to the extent possible by the law (AFMC Handbook, 1995:A-4). The order also encourages granting titles to the result of federally funded R&D to contractors, regardless of size, in exchange for royalty-free use by the government. The National Defense Authorization Act for FY 93 expanded the ability of federal agencies to participate in technology transfer by, among other things, directing the Department of Energy to issue guidelines to facilitate technology transfer to small businesses. The Domestic Technology Transfer Program Regulation of 1988 defines the responsibilities of an ORTA, the Under Secretary of Defense for Acquisition, and the heads of DOD Components (AFMC Handbook, 1995:A-4).

One regulation is Air Force specific. The Air Force Domestic Technology Transfer Policy Directive 61-3 implements the previous directives and defines the purpose of the Federal Domestic Technology Transfer (DT^2) program (AFMC Handbook, 1995:A-5). Specifically, "the Air Force participates in DT^2 to maximize its return on investment in RDT&E" (AFMC Handbook, 1995:A-5).

The regulation process has evolved over time, as indicated above. The regulations are directive in nature, but contain loopholes, in that one must determine if technology transfer is feasible in many situations. What will make an organization spend more than the minimum 0.5% of the R&D budget on technology transfer efforts, as mandated by law?

Technology Transfer – Past Research Efforts

Technology transfer is defined as:

> A process by which facilities, equipment, or other resources relating to scientific or technological developments of a federal laboratory are provided or disclosed by any means to another industrial organization, including a corporation, partnership, limited partnership, or industrial development organization; public or private foundation; nonprofit organization, including a university, or other person to enhance or promote technological or industrial innovation for a commercial or public purpose.
>
> (AFMC Handbook, 1995:O-5)

A thorough review of the literature associated with technology transfer indicates three streams of research: the technology transfer process (and ways to improve the process), technology transfer participants, and technology transfer measurement. This is in line with the definition from the AFMC Handbook, which addresses the transfer process, the organization involved, and the desired outcomes by which to measure the success of the transfer.

Technology Transfer – The Process/Process Improvement

Van Egeren notes that there is much difference of opinion over what steps compose the actual technology transfer process (1997:26). At its most basic, the technology transfer process initiates with the technology being developed by a federal agency, the technology is then placed into the hands of the end user, and the process is completed as the technology is utilized by the end user (AFMC Handbook, 1995:D-1). The basics of this process are similarly defined by Souder, Nashar, and Padmanabhan (1990:5-6). The authors indicate that the technology transfer process involves four stages:

Stage 1- Prospecting: research, analytical, and decision-making activities aimed at screening alternative concepts or technologies;

Stage 2- Developing: physical and laboratory R&D activities focused on enhancing, elaborating, and tailoring the technologies chosen in Stage 1 to meet users' requirements;

Stage 3- Trial: testing the developed technologies in the field;

Stage 4- Adoption: final development, modification, and implementation by the user (Souder et al., 1990:5-6).

The above definitions indicate technology transfer is a fluid, dynamic process in which steps may occur simultaneously, systematically, or be skipped entirely in certain instances. The lack of a well-defined process opens up a plethora of opportunities to improve the process, as the following authors highlight.

Papadakis explores the role of government in the technology transfer process (1995). She notes that the government previously enticed its federal laboratories with "carrots" to perform technology transfer, whereas present-day legislation is more like a "stick" (1995:55). In other words, federal laboratories were previously encouraged to perform technology, but are presently mandated to do so. Of the $23 billion in federal laboratory funds spent on R&D in 1993, 91% belonged to five organizations: the United States Department of Agriculture (USDA), the Department of Energy (DOE), the Department of Health and Human Services (HHS), the National Aeronautical and Space Administration (NASA), and the Department of Defense (DOD) (Papadakis, 1995:57). Papadakis points out that the orientation of most (80%) of the federal laboratory system is government

mission-oriented R&D, which makes it difficult for technology transfer to succeed (1995:55). With this in mind, the author states that technology transfer will be most successful when:

A. The original R&D is undertaken with the end user in mind or at the end user's initiation;

B. Key uncertainties of commercialization are eliminated;

C. There is a strong, existing system for commercialization; and/or

D. New forms of institutional arrangements are created to handle commercialization and technology transfer.

This indicates technology transfers entered into must be thoroughly examined as to their commercialization potential at the outset of the process.

Carr's research indicates two primary reasons showing the importance of improving the technology transfer process. First, there is a widespread perception in industry and government that the nation is not realizing an adequate return for its substantial investment in the federal laboratory system. Second, the federal government is looking for new ways to enhance U.S. competitiveness in the wake of a serious deterioration in the U.S. trade balance (1992A:8). As a comparison, Carr compares the Massachusetts Institute of Technology (MIT) versus the Department of Energy (DOE), a component of the federal laboratory system. Table 1 reveals the results of the comparison:

Table 1. MIT & DOE Comparison

	MIT	**DOE**
$'s spent	$700 million	Over $7 billion
Royalties	2 times that of DOE	½ that of MIT
Licenses	Same	Same

The head of MIT's Office of Technology Licensing responds to these results by estimating an order of magnitude increase in technology transfer from federal laboratories to industry is feasible at the given levels of R&D money (1992A:9). Carr states the discrepancies are related to differences in the technology transfer processes (1992A:9).

In addition to describing the motivation for technology transfer improvement and providing indications that there is room to improve, Carr provides three models to pursue in improving technology transfer (1992A:16). The three models are called the legal, administrative, and marketing models (1992A:16).

Legal model programs, also known as patenting programs, are generally run by the organization's legal staff and focus exclusively on patenting inventions (1992A:16). The motivation behind this model is that organizations cooperating with the government on a specific transfer of technology are given patent rights to the technology being transferred.

The second model is the administrative model, in which programs in universities generally are created as part of an administrative or support organization or are attached to a school or department with active R&D programs (Carr, 1992A:16). Federal laboratories began leaning in this direction during the 1980's technology transfer legislation, in which more effort was placed on evaluating a technology's commercial potential. In addition, there was an increase in licenses of technology (Carr, 1992A:16).

The final model, the marketing model, appears to have the most merit for present day use (1992A:16). In this model, technologies are actively marketed according to their potential for licensing. Carr says there are two primary avenues federal laboratories should explore by using the marketing model. The first is to market available technologies

in a way similar to private laboratories and universities. The second opportunity is to target the large segment of private industry that is unaware of federal laboratory capabilities or are concerned with cooperating in a project with a federal government agency (1992A:16).

In the second part of his research, Carr identifies technology transfer best practices (1992B). Carr implies that a major problem with the federal laboratories' participation in technology transfer is the lack of marketing (1992A:16). However, he recognizes there are some limitations to the federal government's transferring of technology, such as national security (certain pieces of information are not appropriate outside the confines of the federal government), U.S. preference (technology should be transferred within the U.S. first), fairness of opportunity (all should have an equal opportunity to participate in technology transfer), and conflict of interest (especially concerning the participants) (Carr, 1992A:18-19). Notwithstanding, it is important for federal laboratories to conduct marketing, understanding the preceding limitations, as it is recognized that simply placing technology on a shelf is not an effective way of initiating the technology transfer process (Carr, 1992B:27).

After establishing the need for marketing in the technology transfer process, Carr identifies several approaches to marketing (Carr, 1992B:27-28). The first option is entitled the "First-Contact Marketing Strategy" (Carr, 1992B:27). This approach consists of having the inventor or technology transfer's office identify potential transfer partners and having the first firm that demonstrates an ability to participate become the partner. The primary benefit is the ability to minimize the use of scarce resources in finding the

industry participant. This is MIT's approach, which as stated earlier provided them the same number of licenses as the DOE at one-tenth the price tag. The second marketing strategy is called "Focused-Publicity" (Carr, 1992B:28). The primary tenets of this strategy include the use of press releases and computer bulletin boards to make the availability of the technology for transfer known. There is no conclusion made concerning which strategy is better, but instead the importance of marketing is the point made. Different situations require different marketing approaches.

Weijo discusses several strategies available to promote technology transfer (1987). Weijo acknowledges recent changes in legislation have helped the technology transfer process, but he indicates marketing is important, just as Carr argues above. Weijo discusses three different strategies and their associated goals (1987:44-45):

1. **DEMAND PULL** – passive. Wait for the customer to bring ideas to you.

GOAL: make information available to individuals and organizations looking for answers to problems customers have identified.

2. **ROLE-DIRECTED**- active. Private industry engineers, etc. must make the leap between what government technology is being provided and how they can use it.

GOAL: make people inside the organization aware and knowledgeable about the research being conducted in government-sponsored laboratories.

3. **ORGANIZATION DIRECTED**- most active. Government personnel determine who can use the technology and how. (start to finish involvement)

GOAL: "active communication with all important roles involved in developing and implementing technologies in a firm."

Another way to look at this is according to what Weijo defines as the technology transfer continuum, pictured in Figure 1:

Diffuses <--> Focuses				
Audience	Passive	Role-Directed	Firm-Directed	Audience

Figure 1. The Technology Transfer Continuum

The federal agency participating in technology transfer has the option to focus the audience on a specific technology it feels can be used in the commercial sector (the firm-directed approach), or on the other extreme let industry come to them with suggestions and start from scratch (the passive approach). Of course, the transfer process can be executed according to any point between the two extremes. Once again, different situations require different approaches.

Winebrake (1993) studies the mechanisms in place for federally funded technology transfer. Winebrake's research examines the results of 116 case studies in the Department of Energy (1992:55). The first step in technology transfer is the identification of the technology to be transferred. In doing so, one can determine how to market the technology: passively or actively. According to Winebrake, there are five stages of technology development:

1. Basic R&D – new knowledge is discovered
2. Exploratory R&D – attempt to discover an unknown application of technology
3. Applied and Information-Based R&D – research performed to apply basic knowledge to a particular problem
4. Technology Development – R&D is hardware oriented and the application is already designed
5. Market penetration – effort placed on finding market uses of the technology

The maturity of the technology when private industry gets involved in the transfer dictates the stage at which marketing will occur. If the government wants to "push" their technology to the field, private industry will not enter the process until market penetration. If the government is allowing the market to "pull" (drive) which technology it attempts to commercialize, private industry will enter the process much earlier.

In addition to discussing technology stages of development, Winebrake identifies several practices that enhance the "success" of transfers. Success was measured on a 5-point Likert scale (1 meaning not very effective to 5 meaning very effective) by the government agency member primarily responsible for the transfer (Winebrake, 1992:56). Winebrake performed t-tests on a variety of factors assumed to contribute to successful transfer of technology. The two factors found to be significant at a 95% confidence level were having advisory groups and collaboration with cost sharing. Advisory groups (having members of the government and private industry participate together from the outset) were seen to be important because they overcome two significant barriers to the technology transfer process: differing expectations among the two parties, and a lack of awareness of the value of the technology being transferred (Winebrake 1992:57). Collaboration with cost sharing is important for four primary reasons (Winebrake, 1992:57):

A. Cost sharing (and the potential financial losses associated with it) forces recipients to look more carefully at a project before entering into a collaborative agreement, and only those projects showing high success potential are chosen;

B. Cost sharing may attract recipients with money already invested in the technology elsewhere or in some other form, and these recipients bring with them the experience that successful transfers need;

C. Cost sharing assures certain intellectual-property rights or licenses remain protected, and hence, the potential profit incentive of these projects remains;

D. Cost sharing breeds a commitment by both parties to make a project work because only successful projects bring returns to the investor.

The first and last reasons are probably the most important as they require both parties to examine the potential technology transfer before the process begins, and if they agree it is worthwhile, they are required to invest money based upon this decision.

Once both parties agree on the technology to be transferred, they must enter into an agreement. Government legislation has created what is called a Cooperative Research & Development Agreement (CRDA). CRDAs were first authorized by the 1986 Federal Technology Transfer Act (Knauth, 1991:33). Knauth states, "A CRDA is a business contract, not a procurement contract" (1991:35). The government cannot place money toward the CRDA, but can provide other resources such as people, buildings, and services. CRDAs, along with the other legislation concerning technology transfer, is an about face from the government's previous stance on technology sharing. Incentives now are in place for private industry to cooperatively participate with the government in the transfer of technology. Such incentives include patents and licenses (Knauth, 1991:33). Some incentives are in place for government personnel, too. Federal researchers can personally receive a portion of the royalties the government receives from the private company.

Knauth indicates the concept of CRDAs is a good one, but that it still requires some "fine tuning" (1991:38). Psychological barriers associated with existing prejudices on both sides remain as CRDAs and associated legislation have completely reoriented

government and business on this issue. A final barrier to overcome is bureaucracy, a common complaint about the government in general. It is stated that CRDAs often take up to 10 months from conception to signing, an unacceptable time frame considering the types of technologies being transferred. The potential problem is that competitors may be able to place similar products on the market before the companies going through the CRDA process are able to finish this administrative procedure.

A 1994 GAO Report provides more recent documentation concerning CRDAs within the Department of Energy (DOE). The purpose of the study was to identify the benefits associated with CRDAs. It was noted by the authors of the report that costs were completely ignored. The study examined 10 CRDAs and concluded the following:

A. The CRDAs offered opportunities for federal laboratories and industry to collaborate on research while meeting their missions.

B. Technology from federal laboratories was transferred to the private sector, resulting in commercial products.

C. R&D programs were advanced.

D. The sharing of resources aided federal laboratories and private companies in accomplishing CRDA objectives.

These results indicate that CRDAs are helping achieve the objectives of technology transfer, at least for this small sample.

It is apparent from the above research that the technology transfer process, due to its fluidity, requires much coordination and flexibility. What works in one situation doesn't necessarily work in another. An important aspect of technology transfer is understanding

the participants, their roles, and their perceptions. It is this venue of research that is examined next.

Technology Transfer – The Participants

The success of a specific technology transfer, as one might expect, is highly dependent upon the participants. Technology transfers are partnerships and understanding who is involved and what is important to them is of utmost importance. It is a lack of understanding that will either preclude entering into transfer opportunities or degrade the success of transfers pursued. The following research efforts address these issues.

Baron's research is concerned with overcoming barriers to the technology transfer process; a primary one being the differences among participants (1990:38). At the most elemental level, there are two participants in the transfer of any technology: the government and the end user. Baron cites the loss of U.S. leadership in technology as the reason the government is proactively pursuing technology transfer (1990:38). However, companies are hesitant to participate, partly because the government has been a poor partner in the past. Examples of poor government follow-through include nuclear fuel processing, fast breeder reactors, and solar and wind energy. The government enticed private industry to participate in these technological arenas, only to back out (1990:38). In order to overcome the past, an understanding of the other participant and its culture is important. Baron breaks them down in the following way:

Government

1. Performs research for research's sake, not with a particular product in mind.
2. Not concerned about confidentiality; thus, present results at conferences and open forums.
3. No cost-benefit analysis is done to determine whether the research will be profitable.
4. Research is long-term in nature.

Industry

1. Short-term missions for reasonable returns on investment
2. Confidentiality is crucial.
3. Do not view national laboratories as part of the "real world" due to their lack of attention to budgets and schedules.

Having an understanding of the above issues enhances the possibility technology transfers of mutual benefit will occur.

In his research, Roessner examines what industry wants from federal laboratories (1993). In these changing times, industry needs what the federal laboratories can provide and vice versa. Companies are feeling more pressure to look for outside expertise and technology (Roessner, 1993:39). In fact, 84% of industrial R&D is expected to be contracted out in 1997 (Studt and Duga, 1997:2). On the other hand, federal laboratories are being tasked to work with industry more via the stream of technology transfer legislation. These factors appear to provide the foundation for a win-win situation. However, private industry has reservations about entering into technology transfer projects with the government. Private industry managers suggest a major contributor to this perception is that government does not know what industry wants when it comes to technology transfer. Industry admits it needs help, but not the kind of help the government currently provides. Roessner suggests that companies want leverage on their

own R&D projects, not market ready technology and until this point is realized, technology transfer will remain in its current situation (1993:37).

Spann, Adams, and Souder view the participants of technology transfer in a slightly different manner (1995). According to Spann et al., there are three primary participants in the technology transfer process: developers, sponsors, and adopters. Developers "develop and apply technology under government funding and sponsorship;" sponsors "fund technology development, disseminate information about government technologies and/or facilitate its transfer;" and adopters "are private sector firms that incorporate and use the technologies in their commercial processes or products as well as individual end users of the products" (Spann et al., 1995:22). An example of a developer is a federal laboratory such as the Air Force Research Laboratory located on Wright-Patterson Air Force Base, Ohio, and adopters are industrial firms. It is sponsors whose role is unique to define. Sponsors perform "go-between" functions. Technology transfer legislation created Offices of Research and Technology Applications (ORTAs), which fulfill this role within the government (AFMC Handbook,1995:A-2). Once again, an understanding of the participants involved enhances the technology transfer process.

Schroer, Farrington, Messimer, and Thornton describe the function performed by the Huntsville/Madison County Chamber of Commerce with regard to technology transfer. The chamber of commerce acts as a "sponsor" of the technology transfer process in the Huntsville, Alabama area. The mission of the chamber is to help local companies access technology at four federal laboratories located in north Alabama (Schroer et al., 1995:41). They accomplish this in a variety of ways by disseminating information about the

laboratories through telephone calls, company visits, newsletters, fact sheets, seminars and workshops, and other ways (1995:40). This proactive approach has been successful and responsible for much of the technology transfer occurring between the federal laboratories and the local business community. In fact, 65% of participants found out about technology transfer through chamber visits and 10% through chamber publicity (1995:43). Additionally, 55% stated the transfers with which they were involved would increase revenues, 35% would lower cost, both leading to an increase in company profits (1995:43). Schroer et al.'s research indicates that providing information about what the federal laboratory can do to help industry is a positive way of increasing the frequency with which technology transfers occur.

The above research tells a story. Both industry and the government have reasons for pursuing technology transfer. However, the research also reveals that technology transfer is not pursued as much as it might be if parties knew about the other. Communication is key in making technology transfer more common. Now that the process and participants have been identified, the final area of research to be examined is technology transfer measurement.

Technology Transfer – Measurement

Technology transfer has potential benefits embedded in its process. There is money to be made on both sides: government may receive money through royalties from patents and industry can earn money through selling products using the technology transferred. However, this simplistic view is just that, simplistic. In reality, as the following research shows, measuring all of the benefits and costs associated with a particular transfer of

technology is difficult. As of 1994, no measurement method existed which satisfied Air Force technology transfer experts (AFMC/TTO, 1994:6).

Carr defines four measurement models for technology transfer (1992A). The models, which appear below, are proposed knowing that technology transfer measurement is difficult to conceptualize, just as is technology transfer effectiveness:

1. **OUT-THE-DOOR MODEL** – measures something countable, information assets such as brochures, or in the case of the Air Force, licenses and CRDAs. The problem with this model is the numbers hide the magnitude and quality of the counted event. (For example, a single license may transfer a groundbreaking technology, but it would be weighed the same as a transfer of a technology with lesser importance).

2. **MARKET IMPACT MODEL**- desirable since this is the goal of technology transfer. This model often uses royalty income as a measurement, a reflection of the technology's success within the market. However, this model is not very useful because there is often a great deal of time that passes between the technology transfer beginning and the receipt of royalties.

3. **POLITICAL MODEL**- measures items such as the number of reports to Congress, etc. They stress successes and achievements in spending authorized funds.

4. **OPPORTUNITY COST MODEL**- measures what else could be done with the money spent on technology transfer. Not useful at the present time because there is no model in place to adequately measure this.

Of the four suggested, the "opportunity cost" model is the most desirable, yet at the same time is the most out of reach. It is easy to obtain measurements for the first three models, but the information provided is not really meaningful. Consider, for example, the "out-the-door" model using the number of Air Force CRDAs. The Air Force has performed 475 CRDAs since fiscal year 1989 (3 in 1989; 4 in 1990; 17 in 1991; 21 in 1992; 65 in 1993; 85 in 1994; 93 in 1995; 100 in 1996; 81 in 1997) (Guilfoos, 1998B). One can see

that CRDAs have typically increased from year to year, but vital information about them is unavailable through simply counting how many there are. The fourth model, "opportunity cost," is different in that meaningful information for decision-makers can result. If there was a way to measure the opportunity cost associated with a particular CRDA, the R&D manager would be able to make an educated decision on whether or not to spend their R&D dollars in this manner, especially if technology transfer funds are "taken out of hide". This points to the need for a return on investment (ROI) model to measure the benefits associated with the investment a R&D manager makes in a particular technology transfer. Carr's conclusion, unfortunately, is that technology transfer measurement and evaluation require more study as adequate models are not in place (1992A:21). Thus, R&D managers do not have a systematic, logical way to choose appropriate technology transfer opportunities.

Technology transfer effectiveness has been described and measured in a variety of ways via case studies. Winebrake analyzed 116 United States Department of Energy cases and defined success as the effectiveness of the transfer process (1992:56). Souder et al. obtained a sample of forty separate programs from governmental organizations such as NASA, the Department of Energy, and federal laboratories; non-governmental organizations such as private laboratories and a research institute; and university research centers (1990:7). For this article, Souder et al. define successful technology transfer as "... those whose technologies were adopted by more than three-fourths of the targeted user population" (1990:7). Adoption occurred when "... the user made a significant financial and emotional commitment to the routine use of the technology for more than

two years and when the user expressed satisfaction with the technology" (1990:7). Both of these definitions are highly subjective. There is no precedent for them. When considering Souder et al.'s definition, several questions come to mind. What is the target population? What classifies a significant financial commitment? What classifies a significant emotional commitment? Why two years? What classifies an expression of satisfaction? These articles illustrate the difficulty associated with measuring technology transfer.

Gottinger's 1990 article results mirror those of Winebrake and Souder et al. The article discusses the social costs and benefits derived from technologies that have spun off from the Strategic Defense Initiative (SDI). He identifies five primary spin-off technologies: the spock supercomputer; high-speed fault-tolerant technology; bioglass; laser doppler radar technology; and the free electron laser (Gottinger, 1990:688-689). The article describes an "opportunity cost" model. Social benefits are determined by two items, consumer surplus and resource savings for the economy. Consumer surplus is measured by the dollar savings to consumers as a result of price reduction. The price reduction is assumed to occur because learning advances associated with the introduction of new technology make it cheaper to produce products. Resource savings for the economy is a synonym for opportunity cost and is directly related to consumer surplus. Resource savings for the economy is defined as the ability of individuals to spend their money elsewhere because they pay less for the product with enhanced technology. In the end, Gottinger attaches numerical values to the five SDI spin-off technologies for consumer surplus and resource savings. Gottinger concedes the dollar amounts are

inaccurate because they (1) limit benefits experienced to a specific timeframe; and (2) are limited to product price reductions and do not account for product quality improvement. While social benefits are described above, a definition for social costs is more elusive. In fact, Gottinger states that numerical estimates of social costs are impossible (1990:697). Once again, technology transfer measurement is not easy. Gottinger was unable to adequately compare social benefits to social costs, only a portion of the overall benefits and costs related to technology transfer.

Guilfoos documents a working group's plight to find a payoff/benefits indicator to associate with the transfer of technology within the Air Force Materiel Command. The group was specifically gathered to develop a measure of the socio-economic benefits of Air Force technology transfer programs. After much consideration, the Air Force Technology Transfer group of experts determined they would identify one factor to best reflect the benefits and revenues (AFMC/TTO, 1994:4). The group acknowledges from the outset three primary drawbacks to this approach: (1) not all transfers result in revenues; (2) not all benefits are monetary; and (3) money may not be seen for a specific CRDA for a long period of time. Thus, the Air Force technology transfer experts developed a measurement tool with narrow application and admittedly does not have the flexibility to apply to all technology transfers. The metric developed in 1994 has not been further developed or pursued since that time (Guilfoos, 1998A).

The above research indicates a gap in technology transfer research. There are currently no models in place to adequately measure the return on investment associated with a particular technology transfer. A look into common return on investment models will

provide some foundational information from which a model measuring technology transfer returns can be estimated.

ROI Models

In making planning decisions for investments, there are several common methods utilized by organizations to determine where to spend their money. The Accrual Accounting Rate of Return (AARR), the Net Present Value (NPV) and Internal Rate of Return (IRR) methods are well known. Below, each method is briefly explained through simple examples.

Accrual Accounting Rate of Return (AARR)

The accrual accounting rate of return (AARR) method is an income measure divided by a measure of investment. This method is concerned with the affect on operating income when an investment is made. The associated equation is:

$$AARR = \frac{\text{Increase in expected average annual operating income}}{\text{Net Initial Investment}}$$

A simple example below is used to illustrate how AARR is used:

A snow removal company buys a truck to dispense sand on icy roads. The truck is purchased for $40,000 and has no salvage value at the end of a 5-year useful life. It is expected that $15,000 will be earned per year from truck operations. Using straight-line depreciation,

$$AARR = \frac{\$15,000 - (\$40,000/5)}{\$40,000} = \frac{\$15,000 - \$8,000}{\$40,000} = \frac{\$7,000}{\$40,000} = 17.5\%$$

The AARR indicates the rate at which a dollar of investment generates income. In this case, an AARR of 17.5% implies the snow removal company earns $1.18 on each $1 invested in the truck. As one might guess, the higher the AARR the better. However,

there are several factors that often detract from the use of AARR. First, AARR does not track cash flows; and secondly, AARR ignores the time value of money (Horngren et al., 1997:795). It is for these reasons that the AARR method is not utilized in many instances.

Net Present Value (NPV)

While the AARR method neglects the time value of money, the Net Present Value (NPV) adjusts for it. The NPV method is a discounted cash-flow method that calculates the expected net monetary gain or loss from a project by discounting all expected future cash inflows and outflows to the present point in time, using a required rate of return (Horngren et al., 1997:995). NPV focuses upon cash inflows/outflows with cash being invested today in hopes of receiving more in return at a later date. The required rate of return represents the minimum return on investment acceptable; i.e., the return the organization could obtain by spending their money elsewhere in a project of comparable risk (1997:997). The required rate of return is synonymous to the discount rate, hurdle rate, or opportunity cost of capital (1997:783). A project should be entered into if the NPV is greater than or equal to 0, an indication that the investment is profitable. To find the NPV, Horngren et al. group the process into three steps:

1. Sketch the Relevant Cash Inflows and Outflows;
2. Choose the Correct Compound Interest Table;
3. Sum the Present-Value Figures to Determine the NPV.

The following example using the same snow removal company illustrates this process:

The company buys a Truck:	$40,000
Trucks Useful Life:	5 Years
Recurring Cash flows:	$15,000
Required Rate of Return:	8%

Table 2. NPV With $15K Recurring Cash Flows

	Total Present Value	**Present Value of $1 Discounted at 8%**	**Sketch of Relevant Cash Flows**					
Initial Investment	($40,000)	1.000	$15K					
Recurring Cash flows	$13,890	0.926		$15K				
	$12,855	0.857			$15K			
	$11,910	0.794				$15K		
	$11,025	0.735					$15K	
	$10,215	0.681						$15K
NPV	**$19,895**							

As stated earlier, a project should be undertaken if the NPV is nonnegative. With a NPV of $19,895 at the required rate of return of 8%, the snow removal company should definitely purchase the truck. However, what if it is estimated that the recurring cash flows are $10,000 versus the previous $15,000? If that were the case, the situation indicated in the following chart holds. The NPV becomes -$70, which is interpreted as meaning the company would actually lose $70 if they were to purchase the truck. Therefore, in this instance, the truck should not be purchased.

Table 3. NPV With $10K Recurring Cash Flows

	Total Present Value	Present Value of $1 Discounted at 8%	Sketch of Relevant Cash Flows					
Initial Investment	($40,000)	1.000	$10K					
Recurring Cash flows	$9260	0.926		$10K				
	$8570	0.857			$10K			
	$7940	0.794				$10K		
	$7350	0.735					$10K	
	$6810	0.681						$10K
NPV	**$-70**							

As indicated by preceding NPV examples, the NPV requires one to estimate as to what future cash flows will be. It is also limited to quantitative measurements. These two pieces of information make it somewhat difficult to apply the NPV method to all scenarios.

<u>Internal Rate of Return (IRR)</u>

The internal rate of return is the discount rate at which the present value of expected cash inflows from a project equals the present value of expected cash outflows of the project (Horngren et al., 1997:993). IRR is sometimes referred to as the time-adjusted rate of return method. In this method, a project is entered into if and only if the IRR is greater than the required rate of return. The IRR method determines the rate of return at which NPV = 0, representing the point at which cash inflows equal cash outflows (1997:785). Once again, we return to the familiar snow removal example with the following information:

The company buys a Truck:	$39,930
Trucks Useful Life:	5 Years
Recurring Cash flows:	$15,000
Required Rate of Return:	8%

Table 4. Internal Rate of Return With $15K Recurring Cash Flows

	Total Present Value	**Present Value of $1 Discounted at 8%**	**Sketch of Relevant Cash Flows**					
Initial Investment	($39,930)	1.000	$10K					
Recurring Cash flows	$9260	0.926		$10K				
	$8570	0.857			$10K			
	$7940	0.794				$10K		
	$7350	0.735					$10K	
	$6810	0.681						$10K
NPV	**$0**							

As one can see, the NPV is 0 when the discount rate is 8%. Therefore, the IRR is 8%.

Carter examines the above accounting methods and their application to the computer-integrated manufacturing (CIM) arena. In order for CIM to apply these methods, Carter states, "an investment's benefits must be measurable- in dollars saved or earned, in shorter production schedules and in higher sales" (1992:59). Unfortunately for CIM, "soft" benefits are important, but traditional methods are not flexible enough to handle them. In addition to this shortcoming, Carter lists several other problems associated with these methods:

1. The techniques require predictions of future cash flows, something rarely accurately predicted.

2. The models do not enable accounting for nonquantifiable improvements such as an increase in a product's quality and flexibility.

3. Traditional techniques can become mere rituals with people simply "massaging" their numbers to support conclusions drawn.

The same difficulties faced by the CIM community in applying traditional ROI measures are experienced by Air Force technology transfer efforts. Qualitative benefits (such as individual knowledge increased in the technology transfer process) exist and future cash flows (via royalties) are difficult, if not impossible, to accurately predict.

If investments are measured in the manner required by the traditional models, there would be no reason to perform this current research. However, benefits are both quantitative and qualitative. So how does one measure qualitative benefits? The following section examines several approaches to measuring benefits that do not directly translate to dollar figures.

Expansion on Qualitative Measurements

As mentioned above, industry is experiencing difficulty in measuring qualitative attributes and has for some time. An exception appears to be the Natural Gas Industry. This industry, through the use of a computer algorithm entitled Project Appraisal Methodology (PAM), has been very successful in predicting which R&D efforts should be undertaken, resulting in positive ROI.

The Gas Research Institute (GRI) was formed in 1978 with its purpose being to make good decisions: to fund the right projects, to terminate projects not meeting goals, to choose the right performing organizations within the gas industry, and to pick the best path to commercialize products. At the time, natural gas was viewed as a fuel of the past. The PAM methodology, developed in 1975, was first used by the GRI in 1978 to provide

a future for natural gas. PAM has led to good decisions because it causes its users to "walk the middle ground" between two extremes: the "rational actor" model in which decision-makers have perfect information (no uncertainty) based on all quantitative measures, and the "gut feel" approach, solely based on guesses (Burnett et al., 1993B:1022). PAM accomplishes this middle ground by answering 7 basic questions (1993B:1024-1026):

1. What will the project accomplish?
2. What are the potential markets?
3. What impact will each project have on each market?
4. What are the benefits and costs which result from the projected market impacts?
5. What is the probability that the calculated benefits will be achieved?
6. What benefits (if any) will come about if GRI doesn't fund the project?
7. What is the expected impact of the GRI R&D project at a given funding level?

This set of questions evaluates a potential project from its conceptual stage through its completion, including what the organization may lose if it does not conduct the project. The final question is akin to sensitivity analysis, in that GRI looks into the return on investment expected given certain levels of investment. The methodology has been successful for the natural gas industry, with the primary results listed below:

1. A HIGH SUCCESS RATE – PAM is an excellent prediction tool.
   GRI has had 132 successful project commercializations and has a 30% success rate, two times the industry average. "GRI's record of success exceeds that of any other R&D funding organization that has documented its results and even substantially exceeds the reported average of US industrial firms" (Burnett et al., 1993A:50).

2. A HIGH BENEFIT-TO-COST RATIO AND A HIGH RATE OF RETURN
   GRI is more than breaking even on their expenditures (1993A:51).

3. INCREASED GAS AVAILABILITY AT LOWER PRICES
   GRI led a major program to discover natural gas sources like coal seams and sand, with technology they helped invent (1993A:52).

4. INCREASED GAS MARKET SHARE
   More uses for natural gas have been developed by GRI, broadening the consumer base, resulting in more sales (1993A:52).

5. COST SAVINGS IN TRANSMISSION AND DISTRIBUTION
   GRI has developed over 30 technologies which have lessened the costs associated with getting the oil from its natural holding place into the hands of customers (1993A:54).

PAM has been highly effective in achieving the above results because it strikes a workable balance between judgment and formal methodology (Burnett et al., 1993A:50). This flexibility enables quantitative measures to be considered along with experts' thoughts concerning nonquantifiable measures. In addition to the above benefits, the gas industry's gains have passed to related industries such as the steel, glass and aluminum industries (Burnett et al., 1993A:53-54). Although PAM appears to be applicable to estimating ROI for Air Force Technology Transfer, the computer program is not pursued due to its proprietary nature. Instead, this effort continues by exploring a similar approach to PAM which is found in the non-proprietary methodology introduced by Canada and Sullivan.

Canada and Sullivan document how to measure project return on investment without the use of a computer program in their book, *Economic and Multiattribute Evaluation of Advanced Manufacturing Systems*. Just as Burnett et al. describe a balance between quantitative and qualitative benefits of Natural Gas R&D, so do Canada and Sullivan for Manufacturing Technology (1989). Chapter 8 of their book introduces multiattribute decision analysis and basic techniques (1989:211). The elementary steps of the process are to: (1) list all attributes, ensuring they are independent of one another, and (2) weigh

the attributes according to their importance. There are many methodologies associated with both steps. A listing of attributes may be all inclusive or on the other hand might be based on the principle of parsimony, listing those factors contributing the most and ignoring those having only minor contributions (1989:212-213). Weighting of the attributes may be done by the equal weight, rank sum weight, or rank reciprocal weight methods, to name a few (1989:226). This simplistic method allows flexibility in analysis and requires only basic information. These characteristics make their methods desirable to the layperson attempting to determine whether or not to embark upon a specific project.

Canada and Sullivan's multiattribute decision analysis methodology is an excellent tool to use in analyzing the return on investment for Air Force technology transfer. Canada and Sullivan provide a framework in which to gather information concerning both the costs and benefits of technology transfer. Next, the methodology is geared toward expert judgment. This means that the people with the most knowledge concerning technology transfer are the ones providing input concerning costs/benefits. Also, gathering of information is relatively easy and is not time-consuming (NOTE: Attachments A & B were used to gather the information for this research). The bottom line is that the methodology is simple to use and allows for user flexibility (e.g., exhaustive list of costs or inclusion of "most important" costs; and weighting attributes according to equal weight, rank sum weight, or rank reciprocal weight). For these two primary reasons (simplicity and flexibility), the Canada and Sullivan multiattribute decision analysis methodology will be the primary tool utilized to fulfill the objectives of this research effort.

Previous Research on Which to Build

While there currently is no model in place to measure ROI for Air Force technology transfer, some of the parts needed to build that model are present. In order to measure a return on investment, there are two elementary parts: the investment (direct and indirect costs) and the returns (quantitative and qualitative benefits). Below are four past research efforts and how they contribute to the development of an ROI model.

Boyd determined the direct costs of technology transfers in his research (1996). His research effort examined eight transfer projects at an Air Force Laboratory using Activity-Based Costing (ABC). His research allocates the direct costs according to the six technology transfer steps defined by the AFMC Handbook: (1) Strategy, (2) Technology Identification, (3) Marketing, (4) Vehicle Identification, (5) Transfer, and (6) Post-transfer administration. Boyd found that no direct costs were allocated to steps 1-3, step 4 consumed 3% of resources, step 6 consumed 5% of resources, and the remaining 92% of technology transfer resources were dedicated to step 5, the actual transfer (Boyd, 1996:ix). Of that 92%, 80% of those resources were human resource related (Boyd, 1996:ix). Examples of direct costs included equipment, travel, and technicians, but the majority was associated with the scientists and engineers (Boyd, 1996:4-49). It is Boyd's conclusion that having 92% of the resources spent in the transfer stage is good because that is the "rubber meeting the road" stage (1996:5-4).

Van Egeren examined the indirect costs of technology transfer in his recent research effort (1997). Van Egeren's objective was to determine the indirect costs of performing technology transfer (1997:ix). The research attempted to accomplish this by identifying

the resources consumed and activities performed by ORTA organizations. Van Egeren's study covered federal laboratories, Air Logistics Centers, and test centers, where he found significant differences between the laboratories, ALCs, and test centers, and also within them (1997:74). His results were once again measured using the 6 steps of the technology transfer process as a backdrop. Unlike Boyd, Van Egeren found that the first major step, strategy, consumed the most resources (1997:90). In fact, strategy consumed over 25% of ORTA resources. This makes sense because strategy is managerial in nature and falls right into the roles ORTAs were created for, to manage. Marketing, the third task, used over one fifth of the total ORTA resources. In the end, Van Egeren was able to assign an average overhead cost to each CRDA, based upon the CRDAs implementers, whether it be an Air Logistics Center or a federal laboratory, such as Wright Laboratory (1997:89). The specific ORTA cost per CRDA at Wright Laboratory was $12,318.

While Boyd and Van Egeren explored technology transfer costs (direct and indirect, respectively), Braun attempted to define the tangible (quantitative) and intangible (qualitative) benefits associated with technology transfer (1996). Braun's study looked at information on past technology transfers, based on questionnaires filled out by those performing the technology transfer. Braun found many quantifiable and non-quantifiable benefits. Quantifiable benefits included royalty payments, cash reimbursements, work savings, resource savings, productivity increases, effective resource utilization, and data exchange savings (Braun, 1996:44). Non-quantifiable benefits included public relations and goodwill, enhanced morale, technology dissemination, technology improvements, use of additional technologies, enhanced social wealth, follow-on CRDA activities, and

improvements in the transfer process (1996:44). Braun found that qualitative benefits are important, but they are difficult to quantify (1996:65). Problems exist because there is no generally accepted measure available and there is a concern for bias if an expert were given free reign to determine the measurements on their own (1996:65). Nevertheless, Braun succeeded in outlining the attributes considered important to experts, tangible and intangible.

A final technology transfer research effort of interest was completed by Davis (1997). Davis examined Cooperative Research & Development Agreements (CRDAs) and the elements of them that are most important to the federal government receiving benefits from technology transfer projects. From this data, CRDA elements most associated with higher benefits to the government were: quantified manpower requirements, commercial partner's ability to commercialize the specific technology, CRDA technology market information, quantified copyright royalty rates, and quantified sales royalty rates (Davis, 1997:vi). Davis' analysis was performed using 69 CRDAs, a major compilation of data. This data will be utilized as part of the ex post facto study performed in the following chapters.

Technology Transfer and ROI Models

It has been shown there is no one specific model that is directly applicable to measure ROI for Air Force technology transfer. This has contributed to the lack of participation in technology transfer above mandated levels. Traditional methods have drawbacks and current theoretical models do not provide for direct application. Because this situation exists, in this research, an effort is made to create a ROI model by combining pieces of the

models above. This research will examine both qualitative and quantitative measures. As Canada states, "sensitivity analysis is needed because this isn't an exact science" (1989:237). Therefore, this model will provide for the opportunity to perform this type of analysis. Upon completion of this research effort, it is desired that a ROI model will be developed, capable of being used by Air Force decision-makers affiliated with the technology transfer process.

The Air Force technology transfer process should take lessons from previous private sector success. As indicated earlier, the Gas Research Institute (GRI) greatly benefited from the PAM methodology. Recall that three primary benefits of using PAM were:

1. PAM was excellent prediction tool - appropriate technologies were developed.
2. PAM improved GRI's benefit-to-cost ratio and rate of return – higher return on investment.
3. Technologies were developed which lessened other costs – unforeseen benefits resulted.

The model developed in this research effort will contribute to Air Force decision-makers being able to strategically achieve the above three results. While the model developed will not be a "silver bullet", it is a step toward making transfer decisions less "gut feel" and more structured in nature.

Research Question

Which technology transfer opportunities should the USAF pursue in order to receive the greatest ROI?

Summary

This chapter focused on examining research in existence on technology transfer as well as return on investment models (ROI). The chapter reviewed the technology transfer legislation in place, as well as literature concerning the transfer process, its participants, and measurement. The chapter reviewed ROI models and their makeup. It was also shown there is currently no ROI model in place to determine which technology transfer projects should be entered into. Burnett et al. lay the theoretical foundations for developing a return on investment model by their description of the PAM methodology. Canada and Sullivan provide the means to take Burnett et al.'s theory and practically develop a model for measuring Air Force Technology Transfer ROI. Chapter III describes the methodology associated with developing a ROI model suitable for use by Air Force technology transfer decision-makers.

III. Methodology

Introduction

The purpose of this chapter is to develop a model that will enable the determination of return on investment (ROI) of individual CRDAs. This model will be capable of evaluating past CRDAs and maintain the flexibility to perform sensitivity analysis. As shown by the success of the PAM methodology, an ability to measure both subjective and objective benefits is of paramount importance in accurately determining ROI. It was also indicated in the literature review that Canada and Sullivan's multiattribute analysis methodology is capable of capturing the same kinds of information that PAM does. Therefore, Canada and Sullivan's methodology is the primary basis for the model proposed within this chapter.

Data Collection

There are two primary sources of data utilized by this research: previous work on the subject and data gathered specifically for this research by the author. It is important to note that all data discussed in this research is limited in scope to technology transfer efforts of the portion of Air Force Research Laboratory (AFRL) formerly known as Wright Laboratories (WL). This will provide a baseline from which to develop a model, which upon completion, can be calibrated and used by other organizations. The WL portion of AFRL was the target of choice due to its proximity to the Air Force Institute of Technology (AFIT) and the working relationship between its technology transfer experts and those of AFIT. Insight into the gathering of each data set is presented next.

Three sources of data already available from previous research efforts are that from Boyd, Van Egeren, and Davis. Boyd and Van Egeren provide cost information, whereas Davis examines benefits. Placing them together, we have the key elements (i.e., costs and benefits) to determine ROI.

Boyd and Van Egeren collectively address the costs associated with technology transfer. In his 1996 research effort, Boyd determined the direct costs of eight technology transfer projects at Wright Laboratory using Activity-Based Costing (ABC). Boyd determined the total direct cost of 8 CRDAs to be $370,237, an average of $46,280 each (Boyd, 1996:4-46). Van Egeren examined the indirect costs associated with Wright Laboratory CRDAs in his 1997 thesis. Indirect costs were approximated by the ORTA cost per CRDA. His research determined the indirect cost of 82 CRDAs to be $12,318. Boyd and Van Egeren developed average values for CRDA direct and indirect costs. Because their results produced a single value for each cost category, the numbers cannot be applied to the analysis in Chapter IV because they are tantamount to "wash costs" (they are the same for all alternatives). However, their research is important in that it shows that it is possible to calculate the direct and indirect costs associated with CRDAs.

Davis' results are relied on more heavily than those of Boyd and Van Egeren for this research project. In 1997, he examined 69 separate Wright Laboratory CRDAs to determine the objective and subjective benefits associated with each CRDA.

Objective benefits, in general, are benefits that are tangible (can be measured/counted). For technology transfer, Davis identified the following objective benefits: royalty payments, cash reimbursements, license fees, work avoidance, data received, software

received, and hardware received. An objective benefit exists (in each category) if the following questions are answered in the affirmative.

1. Royalties – Did the government receive any kind of royalty payment as a direct result of this CRDA?

2. Cash reimbursement – Did the government receive any kind of cash reimbursement for services performed by the laboratory as a direct result of this CRDA?

3. License fees – Did the government receive any kind of license fees as a direct result of this CRDA?

4. Work avoidance - Did the government realize any financial benefits that are not directly payable as cash as a direct result of this CRDA: specifically work avoidance?

5. Data received - Did the government realize any financial benefits that are not directly payable as cash as a direct result of this CRDA: specifically data received?

6. Software received - Did the government realize any financial benefits that are not directly payable as cash as a direct result of this CRDA: specifically software received?

7. Hardware received - Did the government realize any financial benefits that are not directly payable as cash as a direct result of this CRDA: specifically hardware received?

If objective benefits existed for a CRDA in any/all of the seven categories, dollar estimates were provided to indicate how much of each specific benefit a CRDA contained.

Subjective benefits identified by Davis were: productivity, resource utilization, management, image, morale, and technical capability. Subjective benefits were defined to exist (in each individual category) if the answer to the following questions was "yes":

1. Productivity – Did this CRDA result in productivity increases in the laboratory (e.g., is the lab more efficient in its technology development)?

2. Resource utilization – Did this CRDA result in better utilization of specialized laboratory resources (e.g., more use of a laboratory test facility)?

3. Management – Did this CRDA result in improved management and business practices in the laboratory (e.g., improved skills and techniques through interaction with the partner)?

4. Image – Did this CRDA result in improved laboratory image?

5. Morale- Did this CRDA result in improved morale in the laboratory?

6. Technical Capability- Did this CRDA improve lab personnel technical capability?

Subjective benefits are intangible; that is, they cannot be measured in countable terms, such as dollars. Once it was determined that a CRDA contained such a benefit, a 5-point Likert scale (ranging from 1 being "not important" to 5 being "extremely important") was provided to which experts responded by giving their opinion as to the importance of an individual subjective benefit. The point of this was, if the benefit existed but was not considered to be important by that expert, other alternatives with more desirable benefits should be pursued.

In addition to the previous research efforts, the author gathered new data through the creation and distribution of a survey. The purpose of the survey (Appendix B) was to gather:

1. A measurement of the comparative importance of objective to subjective benefits;

2. A measurement of the importance of individual objective benefits to other objective benefits;

3. A measurement of the importance of individual subjective benefits to other subjective benefits.

The data obtained from this survey provide the final piece of necessary information to enable usage of the Canada/Sullivan multiattribute decision analysis methodology.

Methodology Applicability

The Canada/Sullivan multiattribute decision analysis methodology is located in Chapter Eight of their textbook entitled, *Economic and Multiattribute Evaluation of Advanced Manufacturing Systems*. Those familiar with Air Force technology transfer may wonder if a methodology based upon advanced manufacturing systems is appropriate/applicable to evaluate technology transfer projects. Wright Laboratory is involved in the transfer of various technologies in addition to manufacturing (e.g. avionics). While this is true, Canada and Sullivan allay the fear of inapplicability by clearly stating their methodology is not tied to manufacturing systems alone. There is a fundamental link between advanced manufacturing systems and technology transfer: both contain objective and subjective benefits. The identification of these benefits and then combining them in such a manner as to provide a rank-order of the potential alternate actions is the foundation of the methodology. Of secondary importance is the fact the authors indicate in the preface of their book that Chapter Eight (where the methodology is located) can be utilized independently from the rest of the book (Canada and Sullivan, 1989:xiv). The purpose of their multiattribute decision analysis methodology is to combat two common problems they have identified in highly complex decisions. These problems are quoted below:

A. Inclinations to let feelings overcome logic;

B. Tendencies to take shortcuts that violate formal logic/rationality
(Canada and Sullivan, 1989:11)

Canada and Sullivan's intentions were to attack these two areas. It is the purpose of this research to make this applicable to Air Force technology transfer by providing

decision-makers a "tool" to incorporate logic and "feel" together. The goal of this research is in line with the goal of Canada/Sullivan, to simplify complex decisions through the use of logic. This methodology provides the framework to accomplish this.

Methodology Specifics

The ultimate goal of the methodology is to determine a relative ranking among prospective technology transfer projects. This comparison is accomplished by a weighted evaluation of each. The weighted evaluation (WE_k) is defined in Equation 1:

$$WE_k = (\alpha) * (OM_k) + (1 - \alpha) * (SM_k) \qquad (1)$$

where:
- OM_k – the objective value for alternative k
- SM_k – the subjective value for alternative k
- α – relative importance weighting for objective values versus subjective values, and $(0 \leq \alpha \leq 1)$

The higher the weighted evaluation an alternative has, the more desirable the alternative. Theoretically, the alternative with the highest WE_k is the one that should be pursued. The weighted evaluation for a particular alternative is composed of the objective value for the alternative, the subjective value for the alternative, and the relative importance of the objective to subjective value. The remainder of this section applies these concepts to Air Force technology transfer concepts and terminology through the use of simple, hypothetical data. (NOTE: Chapter IV will contain the actual data collected for this research project).

For Air Force technology transfer, the objective measure for each alternative is composed of:

COSTS*	BENEFITS*
Direct Costs	Royalty Payments
Indirect Costs	Cash Reimbursements
	License Fees
	Work Avoidance
	Data Received
	Software Received
	Hardware Received

(Recall, direct costs were found by Boyd, indirect costs by Van Egeren, and benefits by Davis).*

The objective measurement for a particular alternative (Canada and Sullivan, 1989:233) is found by using Equation 2:

$$OM_k = \frac{OFP_k}{\sum_{k=1}^{K} OFP_k} \qquad (2)$$

where:

OM_k – the overall objective measure for alternative k

OFP_k – the objective measure for alternative k (which is divided by the sum of the objective measures for all alternatives, 1 to K, to obtain OM_k).

K - total number of alternatives

In simple terms, this equation means the objective measurement value for alternative k is equal to the total value of its objective measurements divided by the total value of the objective measurements of all possible alternatives summed together.

For Air Force technology transfer, the subjective measure for each alternative is composed of the following potential benefits:

BENEFITS*
Productivity
Resource Utilization
Management
Image
Morale
Technical Capability

*(*Recall, subjective benefits were found by Davis).*

Furthermore, the subjective measurement for alternative k (Canada and Sullivan, 1989:235) is found by using Equation 3:

$$SM_K = \sum_{i=1}^{N} \text{(subjective attribute weight}_i\text{)} * \text{(subjective evaluation rating}_{ik}\text{)} \qquad (3)$$

where:

SM_k – the overall subjective measure for alternative k
Subjective attribute weight_i – the measure of overall importance of a particular subjective attribute in relation to all other subjective attributes.
Subjective evaluation rating_{ik} – the measure of how much of attribute i alternative k contains.
N - total number of subjective attributes.

The subjective attribute weight (also known as the "unitized weight") indicates the importance of an individual subjective benefit in relation to the other subjective benefits. If one benefit were "1/2 the importance" of all benefits, that benefit would have a subjective attribute weight of 0.50. However, this example will contain the simplest relationship and assume all six subjective benefits are equally important. This implies a subjective attribute weight of 0.1667 for each benefit since the sum total must be 1.0.

The subjective evaluation rating for each are captured by a Likert scale. The following Likert scale is used to "measure" subjective benefits associated with Air Force technology transfer with the highest value being the most desirable:

Table 5. Likert Scale for Subjective Benefits

VALUE	1	2	3	4	5
INTERPRETATION	NOT IMPORTANT	SLIGHTLY IMPORTANT	MODERATELY IMPORTANT	VERY IMPORTANT	EXTREMELY IMPORTANT

Putting this information together, we are able to determine the subjective measurement values for each individual CRDA.

The relative importance weighting for OM_k is a subjective measurement typically determined by the expert utilizing the methodology. In this hypothetical example, let α be 0.5 (i.e., objective and subjective measures are deemed equally important).

At this point, an example is appropriate:

EXAMPLE 3-1:

Given: 3 separate CRDAs with hypothetical inputs:

STEP 1: Determine the OM_k for each CRDA.

Recall Equation 2 is used to determine OM_k.

Table 6. Determining Objective Measurement Values

OBJECTIVE MEASUREMENTS:		CRDA 1	CRDA 2	CRDA 3	CATEGORY TOTALS
COSTS					
Direct Costs		($25,000)	($20,000)	($15,000)	($60,000)
Indirect Costs		($40,000)	($40,000)	($40,000)	($120,000)
BENEFITS					
Royalty Payments		$5,000	$6,000	$7,000	$18,000
Cash Reimbursements		$40,000	$30,000	$50,000	$120,000
License Fees		$1,000	$4,000	$7,000	$12,000
Work Avoidance		$70,000	$45,000	$60,000	$175,000
Data Received		$22,000	$2,000	$0	$24,000
Software Received		$1,000	$0	$3,000	$4,000
Hardware Received		$2,000	$2,300	$2,600	$6,900
	CRDA TOTALS	$76,000	$29,300	$74,600	$179,900
	OM_k =	**0.4225**	**0.1629**	**0.4147**	

As shown in Table 6, the objective measurements for CRDAs 1, 2, and 3 are 0.4225 ($76,000/$179,900), 0.1629 ($29,300/$179,900), and 0.4147 ($74,600/$179,900), respectively. (NOTE: $\sum_{K} OM_k = 1$). Relatively speaking, this implies CRDA1 is superior on the basis of objective measurements alone with CRDA3 a close second. Next, subjective measures are examined.

<u>**STEP 2**</u>: Determine the subjective measurement (SM_k) for each CRDA.

Recall, Equation 3 is used to determine SM_k:

The step-by-step procedure demonstrated in Table 7 is described below:

1. Input CRDA benefit values for each subjective benefit.

2. Sum those values into the "category totals" column.

3. Determine the fractional value of the individual CRDAs benefit value to the entire "category total" and insert into the second portion of the table. (e.g., CRDA1 has a value of 5 for subjective benefit "productivity". The category total is 15. Thus, the fractional value is 0.33).

4. Find the SM for each CRDA by multiplying the unitized weight for each subjective benefit by the fractional value determined in step 3 and summing these up for the individual CRDA. For example, the subjective measurement value for CRDA 1 is:

$$SM_{CRDA1} = (0.167*0.3333) + (0.167*0.2727) + (0.167*0.3636) + (0.167*0.3333) + (0.167*0.3000) + (0.167*0.3333) = 0.3227.$$

Table 7 shows the results for all three CRDAs utilizing the preceding steps. The results indicate that, based on subjective measurements alone, CRDA3 is superior to both CRDA1 and CRDA2.

Table 7. Determining Subjective Measurement Values

SUBJECTIVE MEASUREMENTS:					
UNITIZED WEIGHT	**BENEFITS**	**CRDA 1**	**CRDA 2**	**CRDA 3**	**CATEGORY TOTALS**
0.167	Productivity	5	5	5	15
0.167	Resource Utilization	3	4	4	11
0.167	Management	4	3	4	11
0.167	Image	4	4	4	12
0.167	Morale	3	2	5	10
0.167	Technical Capability	4	3	5	12
UNITIZED WEIGHT	**BENEFITS**	**CRDA 1**	**CRDA 2**	**CRDA 3**	**TOTALS**
0.167	Productivity	0.3333	0.3333	0.3333	1
0.167	Resource Utilization	0.2727	0.3636	0.3636	1
0.167	Management	0.3636	0.2727	0.3636	1
0.167	Image	0.3333	0.3333	0.3333	1
0.167	Morale	0.3000	0.2000	0.5000	1
0.167	Technical Capability	0.3333	0.2500	0.4167	1
	SM_k =	**0.3227**	**0.2922**	**0.3851**	1

To this point, we have seen that CRDA1 is superior on objective measures alone. Also, we have noted that CRDA3 is superior on subjective measures alone. The final factor needed in the multiattribute decision analysis methodology to determine the weighted evaluation for each alternative is α, the relative importance weighting of OM_k. Recall, for this example, α is assumed to be 0.50.

STEP 3: Determine the weighted evaluations for each alternative (WE_k).

Recall, $WE_k = (\alpha) * (OM_k) + (1 - \alpha) * (SM_k)$

Applying this formula, we have:

$$WE_{CRDA1} = (0.5) * (0.4225) + (0.5) * (0.3227) = 0.3726$$

$$WE_{CRDA2} = (0.5) * (0.1629) + (0.5) * (0.2922) = 0.2275$$

$$WE_{CRDA3} = (0.5) * (0.4147) + (0.5) * (0.3851) = 0.3999$$

Thus, CRDA3 is the alternative of choice based upon weighted evaluation values. This highlights the fact that, when objective and subjective benefits are considered together, the alternative of choice may be different than if only objective benefits were considered.

STEP 4: Perform Sensitivity Analysis (if applicable/desired).

There are many possible approaches to sensitivity analysis when utilizing this methodology. One example is to vary the relative importance of objective to subjective benefits (α) from 0 to 1. The results of performing this sensitivity analysis follow in Figure 2. The chart reveals that CRDA3 is the optimal alternative where α ranges between 0 and 0.9.

However, CRDA1 becomes the desirable choice if the decision is based upon objective values only (i.e., $\alpha = 1$).

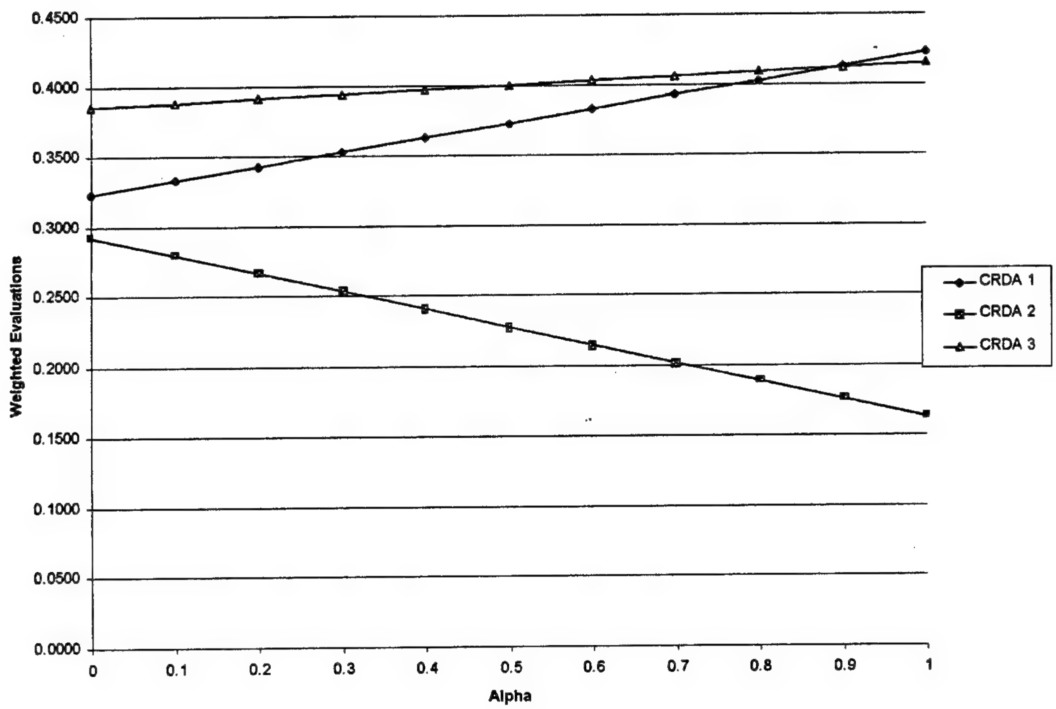

Figure 2. Sensitivity Analysis on Example 3-1 CRDAs

Example 3-1 demonstrates that CRDAs can be evaluated in comparison to one another in a systematic fashion to determine which is more desirable according to costs and benefits. Though systematic and somewhat rigorous, the analysis "tool" allows for expert input (via subjective attribute weightings, subjective evaluation ratings, and the relative importance weighting for OM_k) as shown by Step 4. Thus, a balance between logic (tangible, objective measures) and "feel" (intangibles, subjective benefits) is struck when utilizing the multiattribute decision analysis methodology.

Expectations of the Model

Now that the methodology has been demonstrated, how is it going to be utilized to accomplish the purposes of this research effort? As shown above, the methodology provides a foundation on which to analyze both objective and subjective CRDA benefits. The methodology further shows that a comparison of alternatives is available based upon those benefits. Finally, the example illustrates that the model provides the capability to perform sensitivity analysis by varying certain inputs.

The same principles demonstrated in Example 3-1 will be applied to this research effort's focus: to provide AFRL decision-makers a "tool" for evaluating which CRDA opportunities should be pursued. It has been documented in the previous chapters that WL decision-makers have no systematic way of evaluating CRDAs versus each other. Introduction of this methodology fills this gap.

In order to satisfy the demonstrated need, several pieces of data are incorporated into the model. The first piece of data is the objective and subjective benefit measurements of 65 WL CRDAs. This portion was previously collected by Captain Mark Davis (Appendices A and C). Second, inputs concerning the relative importance of several factors (α and the relative importance of subjective benefits to each other) from four AFRL technology transfer focal points (formerly in WL) are included. This information was obtained from the focal points when they responded to the questionnaire located in Appendix B. Upon receipt of the four responses, the average value of each input was determined. It is these average values that will be used in Chapter IV's analysis.

Finally, the 65 CRDAs are categorized according to four Wright Laboratory directorates (Materials, Propulsion, Avionics, and Flight Dynamics). Categorization is a very important step because this is where the mechanics of the methodology are applicable to the Air Force technology transfer process. Categorization is made according to the two-letter office symbol of the responsible office because this mirrors the current organizational structure within the AFRL as technology transfer focal points (those who are responsible for the decision of which CRDAs to pursue). Second, if a certain category has more than 11 CRDAs (Materials has 31 CRDAs and Flight Dynamics has 16 CRDAs in the data set), these CRDAs are split into subcategories with a maximum of 11 CRDAs in each. This is to approximate reality in that focal points most likely will have less than 11 alternatives to choose from at any given point in time. The restriction to 11 CRDAs enables the results given by the methodology to be more robust as the weighted evaluation (which sums to one over all alternatives) is not spread as thin as it would if all possible CRDAs within a category were examined at once.

After categorization is complete, the four steps illustrated by Example 3-1 take place in each category:

STEP 1: Determine the OM_k for each CRDA.

STEP 2: Determine the subjective measurement (SM_k) for each CRDA.

STEP 3: Determine the weighted evaluations for each alternative (WE_k).

STEP 4: Perform Sensitivity Analysis.

1. The sensitivity analysis to be performed in Chapter IV consists of varying α from 0 to 1. The WE_k's obtained will illustrate how the order of CRDA

preference changes as objective measures vary from being completely unimportant (α=0) to being the only measurement of importance (α=1).

2. A graph will be developed, showing which CRDA is the optimal choice as α takes on different values.

The results obtained by performing these steps will indicate to decision-makers which CRDAs, based on a given level of α, provide the best return on investment in each category. Using this information, decision-makers can look at upcoming CRDA opportunities to see how its objective and subjective benefits line up with the CRDA identified as best by the methodology in a particular category.

In summation, the primary expectation is that the model will help decision-makers to evaluate and compare potential technology transfer opportunities. The model is expected to provide the ability to evaluate past CRDA performance. Secondarily, the model is expected to provide individual decision-makers flexibility to tailor the model according to their preferences and assessment of the importance of individual benefits. The bottom line is that the model is expected to satisfy the objectives of this research effort, to evaluate past CRDA performance and allow for the performance of sensitivity analysis.

Limitations

There are several limitations associated with the multiattribute decision analysis methodology and its application to Air Force technology transfer. First, the methodology is solely based upon user input. It assumes we have captured all possible objective and subjective benefits. Second, the methodology requires experts to delineate between items that might not easily be done (e.g., is morale two times more important than image, three times, etc.). Third, while Example 3-1 contains separate input values for direct costs and

indirect costs, the available Wright Laboratory data is in average values. These critical pieces of information (due to the potential to distinguish between CRDAs) are a "wash" for each alternative in this instance. Therefore, they will be excluded from the actual exercising of the methodology in chapter IV. Though these limitations exist, they can be overcome. For example, benefits associated with technology transfer can be ascertained through periodic questioning of area experts. Nevertheless, the methodology provides decision-makers with a tool in which the relative ranking of technology transfer opportunities is determinable.

Summary

This chapter has introduced the methodology to be utilized in fulfilling the objectives of this research effort. Data collection efforts to obtain the needed inputs for the methodology are discussed. This chapter also provides an example scenario illustrating the mechanics of the procedure. Finally, Chapter III points out how the methodology's use will satisfy the objectives of this research effort. Chapter IV will exercise the methodology using the "real" data gathered concerning technology transfer at Wright Laboratory. Chapter V will be composed of conclusions and recommendations from the results gathered by using the model.

IV. Analysis and Results

Introduction

The objectives of this research effort are to develop an ROI model for technology transfer, exercise the model using previous CRDAs, and demonstrate the model's capability to perform sensitivity analysis. Chapter III illustrated these three objectives using hypothetical data. This chapter will satisfy the research objectives by using actual data. This chapter begins with an overview of how data was collected and is followed by results obtained by applying the model developed in Chapter III to the data.

Data Overview

As discussed briefly in Chapter III, the data gathered for this research is from three primary sources. The first portion of data is the objective and subjective benefit measurements of Wright Laboratory CRDAs. In his 1997 research, Captain Mark Davis collected data concerning 69 separate CRDAs involving four of Wright Laboratory's seven directorates. The objective and subjective benefits considered are those listed in Chapter III and used in Example 3-1 (Appendix A contains this information).

The second portion of data gathered concerns the relative importance of the information found in Davis' work. Several factors (relative importance of objective benefits [α] and the relative importance of subjective benefits to each other) were of prime concern. In order to determine the relative importance of the aforementioned variables, the expert opinion of four AFRL technology transfer focal points (formerly in WL) was obtained. Technology transfer focal points were chosen for the following reasons.

According to the Air Force Program Manager for the Air Force Technology Transfer

program, focal points are the personnel in position to make decisions concerning the pursuit of specific CRDAs (Guilfoos, 1998A). More specifically, among their many duties, transfer focal points are required to (Guilfoos, 1998C):

A. Identify technologies suitable for transfer.

B. Collect, maintain, and report all data elements required for management of transfer.

C. Prepare technology assessments.

D. Take part in public and private sector opportunities for transfer.

E. Provide and disseminate information of federally owned or originated products, processes, services, and facilities.

From this list of responsibilities it is evident that transfer focal points are required to be in the middle of the transfer process and thus are in a position to determine which opportunities should be pursued.

The instrument used to gather focal point inputs is the questionnaire found in Appendix B. Upon receipt of the four responses, the average value for each input (α and relative importance of subjective benefits) was determined. The average value of α (relative importance of objective benefits to subjective benefits) for the four focal points was 0.5625. The relative importance of the individual subjective benefits to each other according to the focal points, which will be used in this chapter's analysis are shown in Table 8:

Table 8. Relative Importance of Subjective Benefits

SUBJECTIVE BENEFIT	RELATIVE IMPORTANCE
Productivity	0.245
Resource Utilization	0.215
Management	0.125
Image	0.145
Morale	0.0825
Technical Capacity	0.1875
TOTAL	1.0000

Interestingly, there was some difference in opinion between the focal points as to which subjective benefits were most important. Table 9 provides the low, high, and average values given for each subjective benefit category.

Table 9. Subjective Benefit Responses: Low, High, Average

BENEFIT	LOW	HIGH	AVERAGE
Productivity	0.16	0.32	0.245
Resource Util.	0.15	0.30	0.215
Management	0.05	0.20	0.125
Image	0.10	0.25	0.145
Morale	0.05	0.16	0.0825
Technical Cap.	0.05	0.25	0.1875
		TOTAL	1.0000

The chart indicates the biggest discrepancies occurred in the importance of technical capability (a difference of 0.20 from low to high response) and the smallest difference occurred with morale (0.11 from low to high response). The remaining four benefits had differences of either 0.15 of 0.16 from the low to high response.

The third and final source of data is the categorization of the CRDAs from the first step. The CRDAs identified were sorted into four separate categorizes representing four Wright Laboratory directorates (Materials, Flight Dynamics, Propulsion, and Avionics).

Four CRDAs did not fit into the primary categories and were deleted. The 65 CRDAs were segregated into categories according to the "two-letter" office symbol of the responsible office. This approach resulted in the distribution of CRDAs shown in Table 10:

Table 10. CRDAs per Directorate

DIRECTORATE	NUMBER OF CRDAs
Materials	31
Flight Dynamics	16
Propulsion	9
Avionics	9
TOTAL	65

The Materials category is arbitrarily broken into three separate sections of 11, 10, and 10 CRDAs, respectively. Similarly, Flight Dynamics is broken into two separate groups of 8 CRDAs each. There are several reasons for this further breakdown within category. First, limiting the number of CRDAs being compared to one another prevents the results obtained from being diluted. In other words, since rankings are based according to weighted values, splitting that weight over less CRDAs provides better results. Second, smaller groups of CRDAs are more representative of reality. A focal point faces the decision to pursue transfer opportunities at a point in time, not over years. Because of this, it is realistic to have only a handful of potential alternatives to pursue (not 16, and definitely not 31).

It is realized that there are many other methods available to splitting the categories (chronological, three-letter office symbol, etc.). However, in an effort to protect the confidentiality of those individuals providing information, delineation of the data points is

stopped at the "two-letter" (or directorate) level. If the data points were further broken down to the "three-letter" level, it would be possible to track the CRDA to the specific individual within the directorate who was responsible for the transfer. This approach is inappropriate due to the restrictions associated with the data garnered and, therefore, further category breakdown was accomplished by randomly assigning CRDAs to individual subcategories.

Data Analysis

Now that the origins of the data have been described as well as the determination of categories, the model is exercised on the seven categories: Materials (3), Flight Dynamics (2), Propulsion (1), Avionics (1).

Materials Directorate

The Materials Directorate "explores new materials and processes for advanced aerospace applications. Its current focus is on thermal protection materials, metallic and nonmetallic structural materials, aerospace propulsion materials, electromagnetic and electronic materials and laser-hardened materials" (Wright-Patterson Air Force Base, 1995:13). One of the most familiar technologies developed in this directorate is composite materials that are used on military and civilian aircraft.

As stated earlier, there are 31 Materials CRDAs in the data set. The CRDAs are arbitrarily split into three separate groups: A, B, and C. The four steps of the Canada and Sullivan methodology are systematically applied to each group individually. This procedure is conducted on each subsequent category as well.

Materials A

Steps 1-3: Obtain objective and subjective measurements, weighted evaluations.

Table 11 indicates the results of step three for the Materials A category using the α of 0.5625 obtained from the technology transfer focal points:

Table 11. Materials A Objective, Subjective, and Weighted Evaluations

MATERIALS A			
	OM_k =	SM_k =	WE_k =
CRDA 1	0.0000	0.0607	0.0265
CRDA 2	0.0000	0.0071	0.0031
CRDA 3	0.0000	0.0106	0.0046
CRDA 4	0.5048	0.2346	**0.3865**
CRDA 5	0.0190	0.0825	0.0468
CRDA 6	0.0000	0.0494	0.0216
CRDA 7	0.0000	0.0494	0.0216
CRDA 8	0.0000	0.0494	0.0216
CRDA 9	0.0381	0.1834	0.1017
CRDA 10	0.0000	0.0106	0.0046
CRDA 11	0.4381	0.2623	**0.3612**
TOTAL	1.0000	1.0000	1.0000

On the basis of using the focal points' value for α, CRDA4 appears to be the optimal choice of the 11 CRDAs within the Materials A category ($WE_k = 0.3865$), though CRDA11 is nearly as good with a weighted evaluation value of 0.3612. How does this relationship change as α is allowed to take on values ranging from 0 to 1? In other words, will CRDA4 remain the alternative of choice as the importance of objective measurements are allowed to range from completely unimportant to solely important? Step four of the methodology reveals this answer. *(Note: The total column values of one simply indicate that the totals for objective measurements, subjective measurements, and weighted evaluation values are one. This practice, a "sanity check", is continued throughout the remaining six cases).*

STEP 4: Perform Sensitivity Analysis.

Sensitivity analysis is performed by allowing α to vary from 0 (objective benefits being completely unimportant) to 1 (objective benefits being completely important). *(Note: This practice is also followed in the remaining six cases).* Figure 3 illustrates how the optimal CRDA choice changes as objective benefits range from being unimportant to all-important.

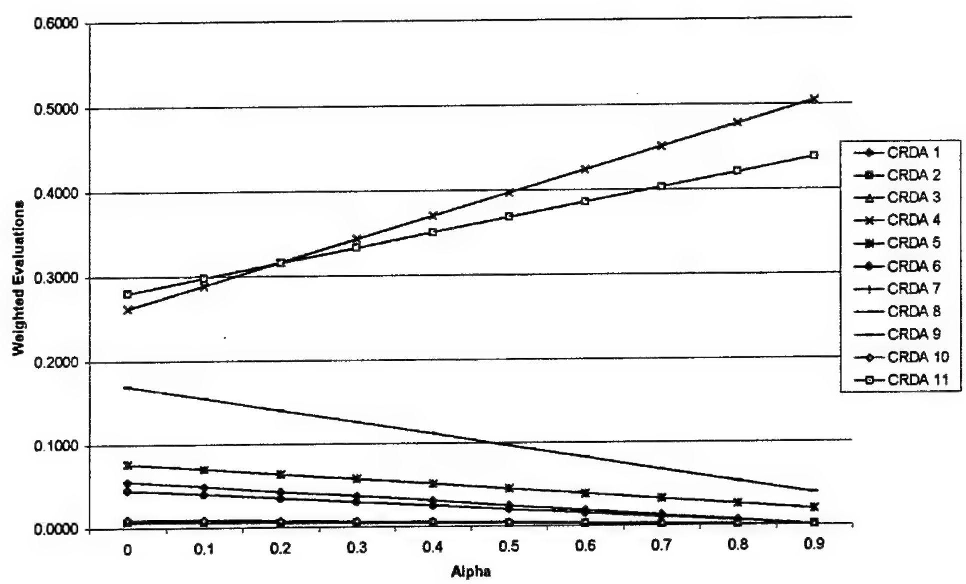

Figure 3. Sensitivity Analysis on Materials A CRDAs

Figure 3 indicates that CRDA4 is the superior choice as long as $\alpha \geq 0.2$ (in other words, subjective benefits are not greater than 80% of the overall importance). However, if the importance of objective benefits falls below the 20% level, CRDA11 becomes the optimal choice. Of interest also is the fact that the remaining nine CRDAs are not even close to being the optimal choices, no matter the value of α. Therefore, depending upon the

importance of objective benefits, the optimal choice is either CRDA4 or CRDA11. If the budget enables the pursuit of three CRDAs, the choice of CRDA to accompany CRDAs 4 and 11, at any level of α, is CRDA9.

Materials B

Steps 1-3: Obtain objective and subjective measurements, weighted evaluations.

The second category of material results for steps one through three are shown in Table 12:

Table 12. Materials B Objective, Subjective, and Weighted Evaluations

MATERIALS B			
	OMk =	SMk =	WEk =
CRDA 12	0.1670	0.2200	0.1902
CRDA 13	0.2783	0.2151	0.2507
CRDA 14	0.1237	0.1183	0.1214
CRDA 15	0.1237	0.1187	0.1215
CRDA 16	0.1328	0.1370	0.1347
CRDA 17	0.0000	0.0000	0.0000
CRDA 18	0.0508	0.0253	0.0396
CRDA 19	0.0000	0.0000	0.0000
CRDA 20	0.0618	0.0756	0.0679
CRDA 21	0.0618	0.0900	0.0742
TOTAL	1.0000	1.0000	1.0000

The results in Table 12 indicate that CRDA13 has the highest weighted evaluation overall (0.2507) with CRDA12 following (0.1902). There is a group of CRDAs (14, 15, and 16) that are all at the next level. The remaining CRDAs appear to be unattractive options.

STEP 4: Perform Sensitivity Analysis.

Figure 4 shows how the order of CRDA preference changes as α varies from 0 to 1.

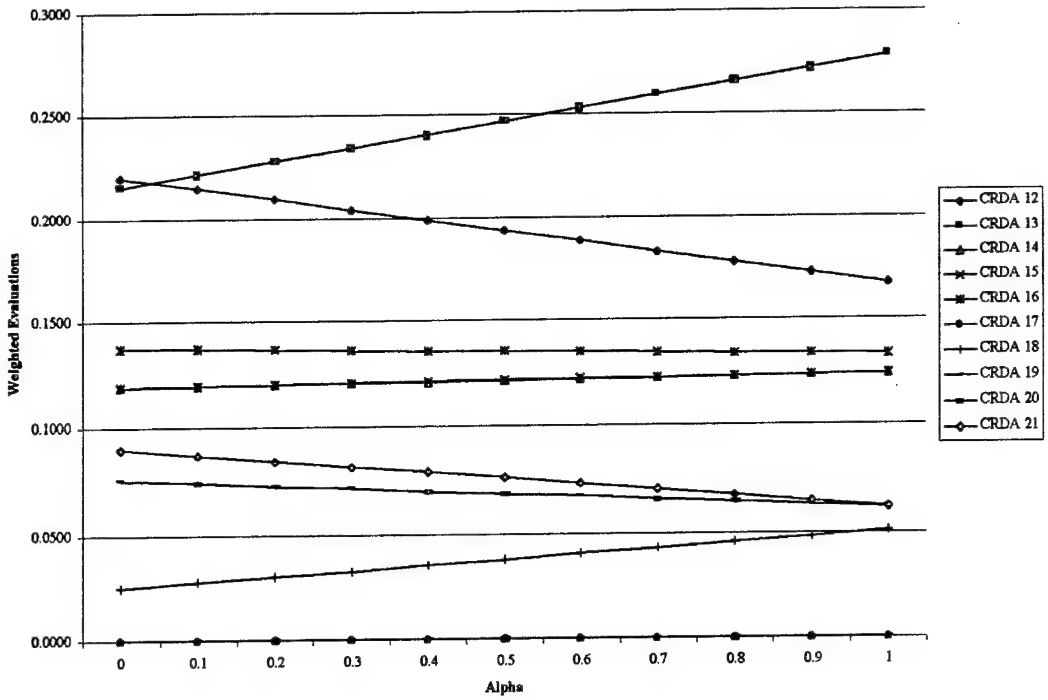

Figure 4. Sensitivity Analysis on Materials B CRDAs

It is apparent from Figure 4 that CRDA13 is superior at every point where $\alpha > 0.05$. In other words, as long as subjective benefits are not more than 95% of overall benefit importance, CRDA13 is the optimal choice according to the model. Additionally, CRDA13 becomes more dominant is α increases. Figure 4 also reveals that CRDA12 is consistently second choice indicating a robust choice. It is also shown that CRDA16 is consistently third. While CRDAs 13 and 12 have some vertical slope to them, CRDA 16's weighted evaluation line appears nearly horizontal (i.e., slope equal to zero). The reason for this is that CRDA16 is solid in both the objective and subjective measures. This means the CRDA not only provides monetary rewards, but subjective benefits, too. CRDAs 14 and 15 are the next choice of alternatives. They are nearly identical to each other and both

have nearly horizontal slopes, similar to CRDA16. After these two CRDAs, the remaining options appear to be nondesirable.

Materials C

Steps 1-3: Obtain objective and subjective measurements, weighted evaluations.

Table 13 indicates the results of step three for the Materials C category using an α of 0.5625:

Table 13. Materials C Objective, Subjective, and Weighted Evaluations

MATERIALS C			
	OMk =	SMk =	WEk =
CRDA 22	0.0000	0.0782	0.0342
CRDA 23	0.0000	0.0078	0.0034
CRDA 24	0.0000	0.0118	0.0051
CRDA 25	0.8983	0.3974	**0.6792**
CRDA 26	0.0339	0.1003	0.0630
CRDA 27	0.0000	0.0534	0.0234
CRDA 28	0.0000	0.0534	0.0234
CRDA 29	0.0000	0.0534	0.0234
CRDA 30	0.0678	0.2323	0.1398
CRDA 31	0.0000	0.0118	0.0051
TOTAL	1.0000	1.0000	1.0000

Table 13 indicates CRDA25 ($WE_k = 0.6792$) is by far the most desirable of the 10 CRDAs within this category. The only other CRDA with a weighted evaluation value of any significance is CRDA30 ($WE_k = 0.1398$).

STEP 4: Perform Sensitivity Analysis.

Figure 5 is the basis for sensitivity analysis in category Materials C.

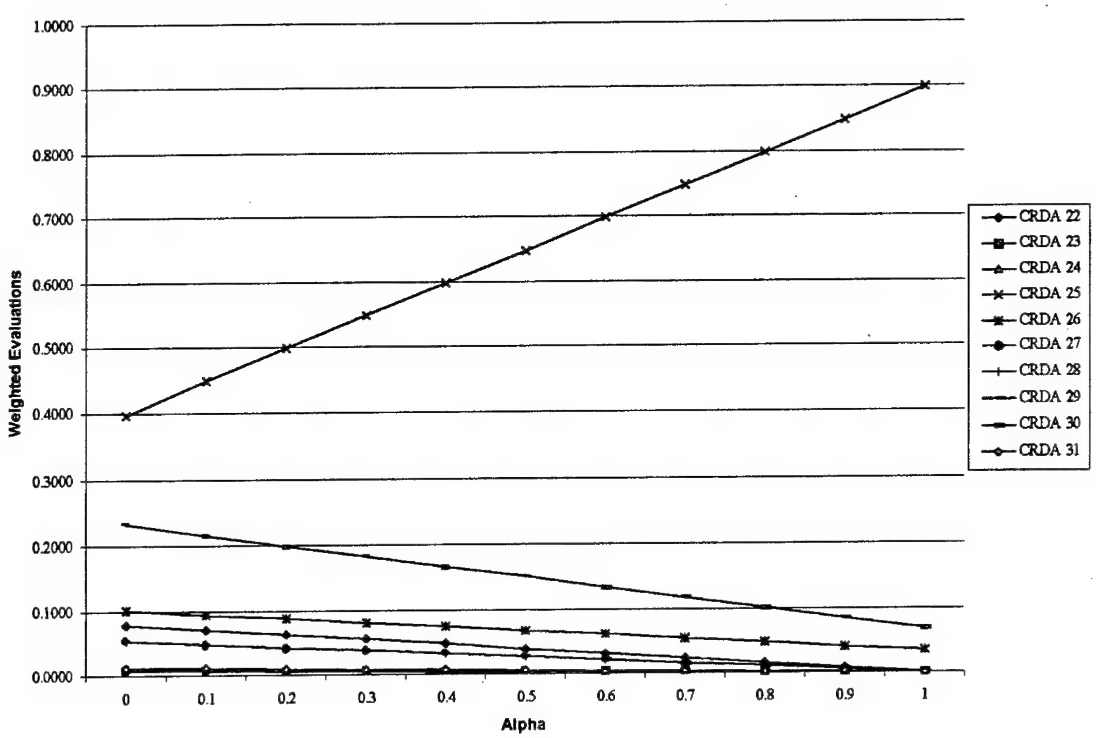

Figure 5. Sensitivity Analysis on Materials C CRDAs

Figure 5 indicates that one alternative is far and away the most desirable choice. That alternative is CRDA25, the optimal choice at all levels of α. Interestingly, CRDA25 is the only choice that's desirability increases with α. This means that while CRDA25 is superior to all other alternatives on the basis of subjective benefits alone, CRDA25 is even more superior to the remaining choices when objective benefits are considered alone. After the optimal choice, CRDA30 is the consistently second. However, its position as second decreases in strength as α increases. Finally, the remaining CRDAs appear to be equally undesirable.

Flight Dynamics Directorate

The Flight Dynamics Directorate "conducts a full spectrum of flight vehicle research. Primary areas of interest include aircraft structures, vehicles subsystems (e.g., landing gear, transparencies), flight control, and aeromechanics" (Wright-Patterson Air Force Base, 1995:12). Additionally, Flight Dynamics is the directorate responsible for experimental test vehicles used to demonstrate integrated technologies in the air (Wright-Patterson Air Force Base, 1995:12).

The Flight Dynamics directorate has 16 CRDAs in the data set. The CRDAs are arbitrarily split into two groups of eight. The four steps to the methodology are systematically applied to the Flight Dynamics directorate CRDAs.

Flight Dynamics A

Steps 1-3: Obtain objective and subjective measurements, weighted evaluations.

Table 14 indicates the results of step three for the Flight Dynamics A category:

Table 14. Flight Dynamics A Objective, Subjective, and Weighted Evaluations

Flight Dynamics A			
	OMk =	SMk =	WEk =
CRDA 1	0.2994	0.1798	**0.2471**
CRDA 2	0.0000	0.2174	0.0951
CRDA 3	0.6956	0.3765	**0.5560**
CRDA 4	0.0000	0.0000	0.0000
CRDA 5	0.0000	0.0000	0.0000
CRDA 6	0.0000	0.0673	0.0294
CRDA 7	0.0000	0.0000	0.0000
CRDA 8	0.0050	0.1590	0.0724
TOTAL	1.0000	1.0000	1.0000

CRDA3, by far, is the optimal choice in this group ($WE_k = 0.5560$). The second choice is CRDA1 ($WE_k = 0.2471$). It does not appear this relationship would vary as α changed from 0 to 1. However, step four indicates whether or not this is correct.

STEP 4: Perform Sensitivity Analysis.

Sensitivity Analysis for Flight Dynamics A is performed with the help of Figure 6.

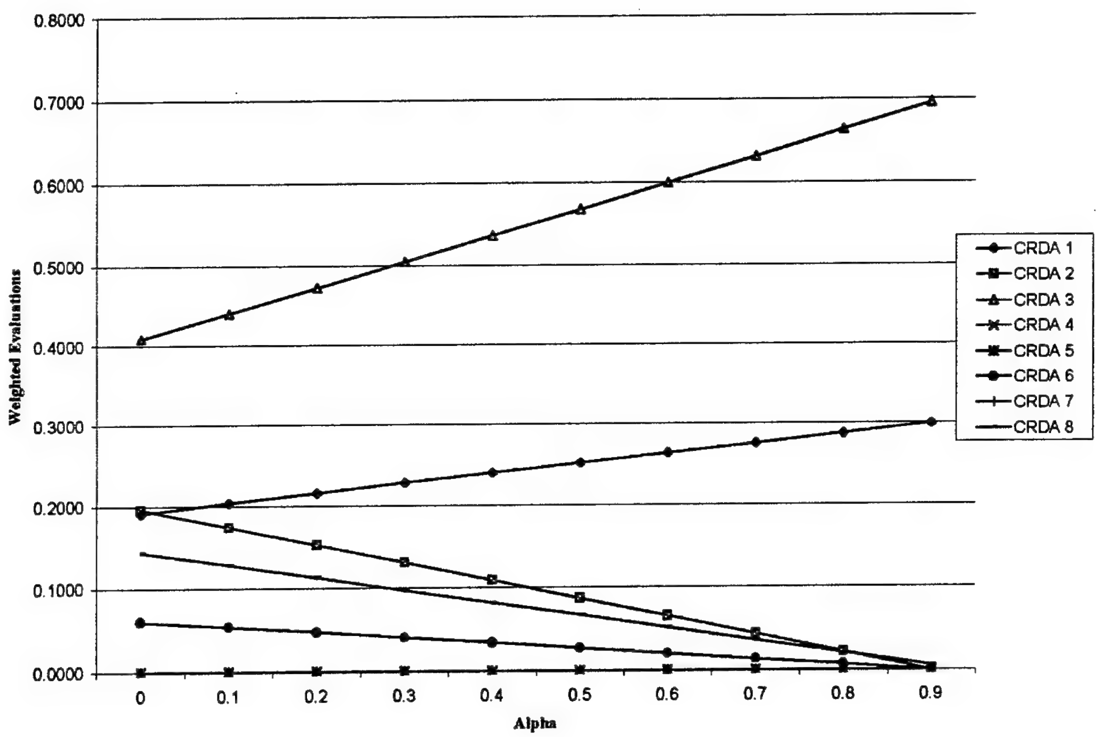

Figure 6. Sensitivity Analysis on Flight Dynamics A CRDAs

The results of Figure 6 indicate that CRDA3 is always the optimal choice. The figure also indicates that CRDA3 becomes even more dominant as objective measures become more important. The second choice (in all cases where $\alpha > 0$) is CRDA1. CRDA1 follows the same relationship as CRDA3 as it too gets stronger as objective measures increase in importance. The remaining CRDAs follow a pattern opposite to CRDAs 3 and 1. Their

weighted evaluation values become smaller as objective measures become more important. It is noted though that CRDA2 finishes third at all levels of $\alpha > 0.05$.

Flight Dynamics B

Steps 1-3: Obtain objective and subjective measurements, weighted evaluations.

Table 15 indicates the results of steps one through three for the Flight Dynamics B category using an α of 0.5625:

Table 15. Flight Dynamics B Objective, Subjective, and Weighted Evaluations

Flight Dynamics B			
	OMk =	SMk =	WEk =
CRDA 9	0.0000	0.0747	0.0327
CRDA 10	0.0000	0.0243	0.0106
CRDA 11	0.7612	0.1212	**0.4812**
CRDA 12	0.0000	0.0000	0.0000
CRDA 13	0.0000	0.2100	0.0919
CRDA 14	0.0896	0.1285	0.1066
CRDA 15	0.0000	0.0855	0.0374
CRDA 16	0.1493	0.3558	**0.2396**
TOTAL	1.0000	1.0000	1.0000

CRDA11 is the superior choice in this group with a weighted evaluation value of 0.4812. The second best choice is CRDA16, which has a weighted evaluation value over double the next best CRDAs, 13 and 14.

STEP 4: Perform Sensitivity Analysis

Figure 7 contains the results of performing sensitivity analysis on Flight Dynamics B CRDAs.

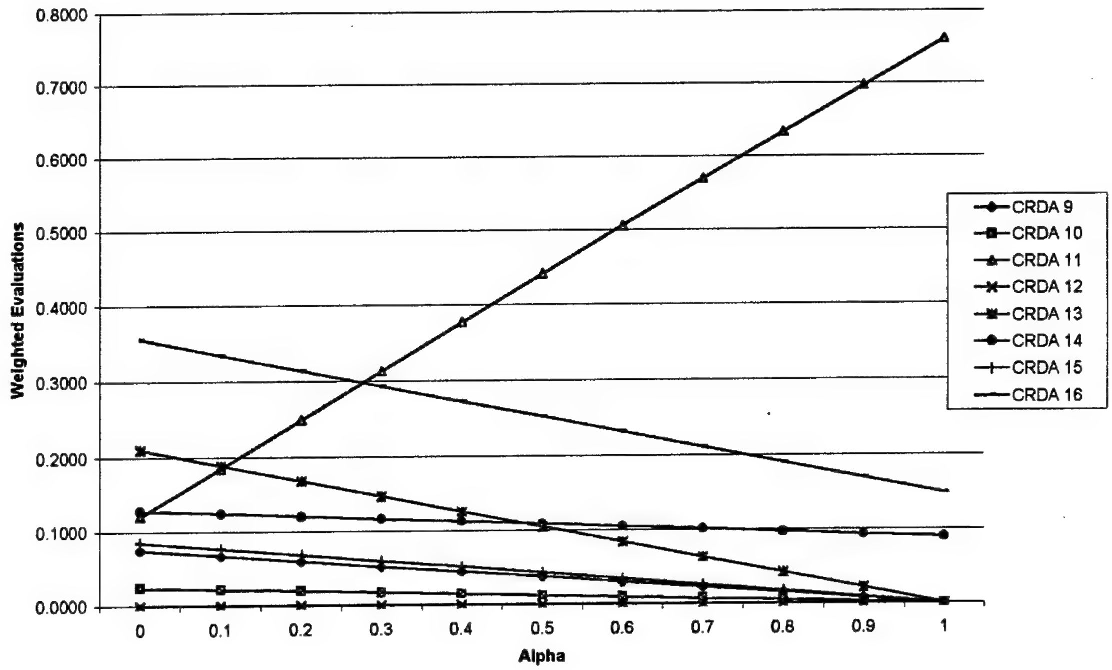

Figure 7. Sensitivity Analysis on Flight Dynamics B CRDAs

Figure 7 indicates results that are more complicated than those illustrated in the previous four categories. There are many more places where alternatives cross each other. These points of intersection indicate where one CRDA becomes more optimal than the other. According to the figure, CRDA11 is fourth most desirable when α is 0. However, when α increases to 0.3, CRDA11 vaults into first place. CRDA11 is the only one that increases as objective measurements gain more importance relative to subjective benefits. CRDA16 is a solid choice, always ranking either first or second. The CRDAs sitting in third and fourth place depends upon the value of α. CRDAs 13 and 14 have relatively the same weighted evaluations, but 14 is more stable across the gamut of alpha (less slope) whereas

13's strength is when α is small. Therefore, the choice of third most optimal alternative depends upon the relative importance of objective and subjective measures.

Propulsion Directorate

The Propulsion Directorate (also known as the Aero Propulsion and Power Directorate) "focuses on air-breathing propulsion and aerospace power technology, which includes fuels and lubricants, turbine engines, and high-performance, high-Mach, air-breathing propulsion applications. Aerospace power research centers around electrochemical energy storage, hyperconducting generators, and power conditioning subsystems" (Wright-Patterson Air Force Base, 1995:12). The Propulsion directorate has 9 CRDAs associated with this research. The multiattribute decision analysis methodology will now be applied to the propulsion CRDAs.

Steps 1-3: Obtain objective and subjective measurements, weighted evaluations.

Table 16 indicates the results for the propulsion category using an α of 0.5625:

Table 16. Propulsion Objective, Subjective, and Weighted Evaluations

PROPULSION			
	OMk =	SMk =	WEk =
CRDA 1	0.0094	0.1672	0.0784
CRDA 2	0.0000	0.0000	0.0000
CRDA 3	0.0000	0.0809	0.0354
CRDA 4	0.0003	0.1078	0.0473
CRDA 5	0.9870	0.0415	**0.5733**
CRDA 6	0.0000	0.3766	**0.1647**
CRDA 7	0.0000	0.1068	0.0467
CRDA 8	0.0002	0.0280	0.0124
CRDA 9	0.0031	0.0912	0.0416
TOTAL	1.0000	1.0000	1.0000

CRDA5 is the superior choice in this group with a weighted evaluation value of 0.5733. CRDA6 is the only other option with a considerable weighted evaluation value (0.1647).

STEP 4: Perform Sensitivity Analysis

Figure 8 contains the basis for sensitivity analysis of Propulsion CRDAs.

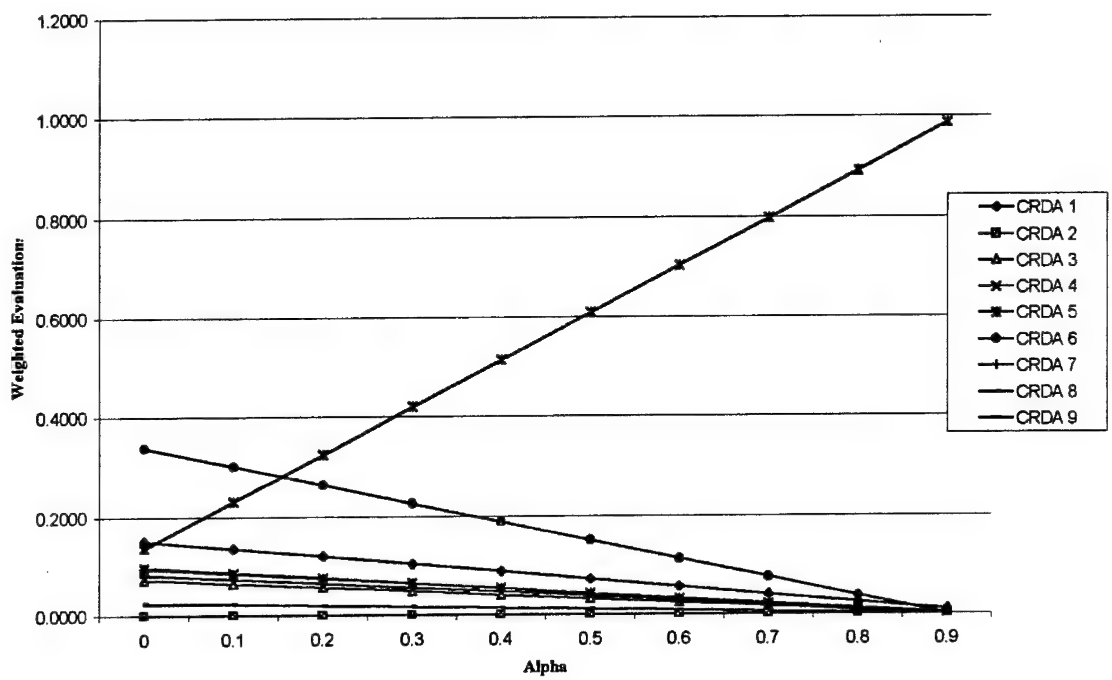

Figure 8. Sensitivity Analysis on Propulsion CRDAs

Figure 8 presents results that are similar to those in the previous category as illustrated by Figure 7. The main point of comparison is the importance of the value of α. Both categories contain a CRDA with a steep positive slope associated with the weighted evaluation line. In the case of Figure 7, CRDA11 possesses the steep positive slope. In this category, CRDA5 has the steep positive slope. In fact, CRDA5 is the only choice with a positive slope. Consequently, as objective measures become of greater importance, CRDA5 is optimal choice by a greater distance. Figure 8 indicates CRDA5 is not the

superior alternative when α is low; however, once α rises past 0.15, CRDA5 maintains the top ranking. When α is low, CRDA6 is the superior alternative. It should be noted that CRDA6 is always second best, representative of a solid, robust option. CRDA1 is second best with subjective measures only (α=0).

Avionics Directorate

The Avionics Directorate is the final one analyzed in this effort. The Avionics Directorate "conducts research and development activities in the fields of offensive sensors (e.g., radar, infrared search and track, forward looking infrared), weapon delivery systems, reconnaissance, electronic warfare, navigation, communications, and avionics integration" (Wright-Patterson Air Force Base, 1995:13). There are nine avionics CRDAs in this study. The Canada/Sullivan methodology is applied to them next.

Steps 1-3: Obtain objective and subjective measurements, weighted evaluations.

Table 17 indicates the results of step three for the Avionics category:

Table 17. Avionics Objective, Subjective, and Weighted Evaluations

AVIONICS			
	OM_k =	SM_k =	WE_k =
CRDA 1	0.2119	0.0622	**0.1464**
CRDA 2	0.1271	0.2097	**0.1632**
CRDA 3	0.0000	0.1523	0.0666
CRDA 4	0.0424	0.1829	0.1038
CRDA 5	0.0254	0.3657	**0.1743**
CRDA 6	0.0000	0.0000	0.0000
CRDA 7	0.0424	0.0000	0.0238
CRDA 8	0.1059	0.0000	0.0596
CRDA 9	0.4449	0.0272	**0.2622**
TOTAL	1.0000	1.0000	1.0000

CRDA9 is the optimal choice in the avionics category with a weighted evaluation value of 0.2622. However, there are three CRDAs that are relatively close in the race for second place (CRDA5, CRDA2, and CRDA1).

STEP 4: Perform Sensitivity Analysis.

Figure 9 indicates how the avionics CRDAs weighted evaluation values change as α ranges from 0 to 1.

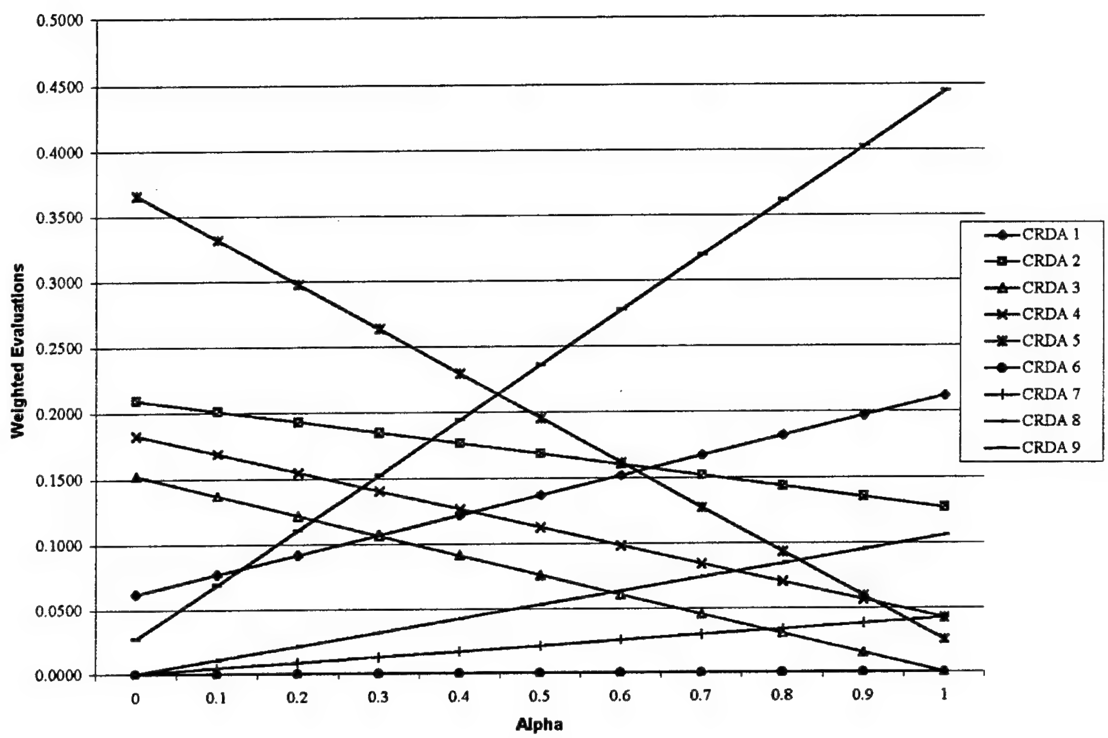

Figure 9. Sensitivity Analysis on Avionics CRDAs

Situations such as the one illustrated in Figure 9 highlight the flexibility of the multiattribute decision analysis methodology. It highlights the flexibility of the tool in that the order of preference truly depends on the α chosen by the decision-maker. For example, if $\alpha = 0.8$, then the top 5 in order of decreasing preference is: 9, 1, 2, 5, and 8.

However, if α= 0.2, then order of the top 5 changes to: 5, 2, 4, 3, and 9. By simply comparing the numbers, one can see that this is a big difference. CRDA1, second best at α=0.8 is no longer in the top 5 at the new α. The same holds true for CRDA8 which does not appear in the top 5, being replaced by CRDA4.

In contrast to the previous six categories, Avionics CRDAs all possess relatively steep slopes. These slopes indicate a difference in the CRDAs ranking versus each other as objective measurements become more important relative to subjective measurements (as α increases). This indicates that each particular CRDA is not as robust across all levels of α as CRDAs with slopes near zero (a horizontal line).

Summary

This chapter applied the multiattribute decision analysis methodology to 65 Wright Laboratory CRDAs with appropriate comments made for each category. The methodology is shown to be applicable to this arena as well as capable of providing the manager flexibility in decision-making.

The results obtained through the use of the multiattribute decision analysis methodology varied in level of complexity. The first directorate (Materials) contained 31 CRDAs that were split into three separate groups. The results of all three groups indicated that the CRDAs retained their rankings in relation to each other over the range of α. This implies that choosing CRDAs in these groupings was relatively simple. The second directorate (Flight Dynamics) had 16 CRDAs which were split into two groups of eight. In contrast to the Materials CRDAs, Flight Dynamics CRDAs possessed less "cut-and-dried" results. Specifically, the Flight Dynamics B category contained CRDA11

which, depending on the level of α, ranged from being the fourth most desirable option to the first. The third directorate (Propulsion) contained nine CRDAs. Propulsion's results were similar to that of Flight Dynamics B. CRDA5 of this category ranged from third place to most optimal as α took upon different values. The final category (Avionics) provided results on the opposite end of the spectrum from those observed in the first category (Materials). Analysis was performed on nine Avionics CRDAs. The results cannot be summed up as quickly here as they were for the other three directorates. As pictured in Figure 9, there are many points at which the weighted evaluation lines for CRDAs cross each other. As stated earlier, it is at these points of intersection where the order of preference between CRDAs changes. Figure 9 highlights the importance of this methodology to decision-makers. The order of CRDA preference depends on the relative importance the decision-maker places upon objective measures. It is this order that the methodology reveals.

Looking forward, Chapter V will contain conclusions concerning the methodology including identified strengths, limitations, and usage. Additionally, managerial implications will be drawn from the results of Chapter IV. Recommendations of future research topics as well as an overall summary will conclude this research effort.

V. Conclusion

Introduction

According to the Air Force Materiel Command Technology Transfer Handbook, the purpose for participation in technology transfer is to maximize return on investment in RDT&E (1995:A-5). However, the Air Force currently has no model in place to measure the return on investment of transfer opportunities (Guilfoos, 1998A). This research was performed in an effort to eliminate this gap. To this extent, the purpose of this research effort as outlined at the outset in Chapter I was to satisfy the following three research objectives:

A. **Propose a ROI model to be used by Air Force decision makers in performing Technology Transfer;**

B. **Evaluate the Return on Investment (ROI) of past Technology Transfers;**

C. **Perform Sensitivity Analysis on Technology Transfers when some inputs are uncertain.**

The first objective was satisfied with the introduction of the multiattribute decision analysis methodology in Chapter II and a hypothetical demonstration of its application in Chapter III. The second objective was satisfied in Chapter IV as the methodology was applied to 65 Wright Laboratory Cooperative Research & Development Agreements (CRDAs). The third objective was satisfied through the analysis of the CRDAs. Sensitivity analysis was performed by varying the parameter that measured the relative importance of objective benefits versus subjective benefits (α). Therefore, by satisfying the three research objectives, this effort provides Air Force decision-makers a model on which to determine the ROI associated with each CRDA.

In the process of satisfying the primary research objectives, several interesting conclusions resulted which will be discussed next. They are followed by the managerial implications of those results. A discussion of areas for future research as well as an overall summary will conclude this effort.

Conclusions

Given that this methodology is the first attempt to simultaneously measure the quantitative and qualitative benefits of Air Force technology transfer, there are both strengths and limitations. These strengths and limitations apply not only to the model, but also to the gathering of inputs for the model. These areas are discussed below.

Strengths

1. **Applicability & ability to provide information that promotes decision-making in a variety of circumstances:** The multiattribute decision analysis methodology presented by Canada and Sullivan is applicable to the Air Force for usage in determining the ROI of individual technology transfer opportunities. The methodology enables leaders to make decisions by striking a balance between "hard and fast numbers" (objective benefits) and "gut feel" (subjective benefits). The systematic methodology can be successfully applied to distinguish between alternatives on the basis of the objective and subjective benefits each option possesses in comparison to one another. The results of applying the methodology to seven separate categories in Chapter IV show the methodology is able to handle a long continuum of scenarios. On one extreme, the methodology can illuminate a situation where there is a definite superior option no matter the importance placed on objective versus subjective benefits (Material C, Flight Dynamics A category). On the

other extreme, the methodology highlights situations where the choice is not so clear-cut and depending upon how the decision-maker values objective benefits the CRDA of preference changes (Flight Dynamics B, Avionics).

2. **Built on related research provided by experts:** The inputs utilized to exercise the model in Chapter IV were obtained from Air Force technology transfer experts. First, the determination of the objective and subjective benefits experienced by the Air Force in technology transfer were developed in the research by Braun and Davis. In addition to benefit definition, the amount of benefits associated with each CRDA were gathered by Davis. Objective benefits were measured in dollars, while subjective benefits were measured according to a 5-point Likert scale. Additionally, technology transfer focal points (the ultimate users of this model) were summoned to provide their estimation of the relative importance of benefits to each other.

Limitations

1. **Proprietary Data:** Several limitations are associated with the fact that all data for this effort was collected with the assurance of confidentiality. Consequently, this led to splitting up the data concerning the Materials and Flight Dynamics directorates at the "three letter" (directorate) level in an arbitrary fashion. Therefore, the results obtained in Chapter IV are not to be directly applied, but instead are meant to show that, given the necessary data, a ranking of transfer opportunities can be obtained.

2. **Validation:** Closely related to the first weakness is the idea of validation. It is not feasible to validate these particular results. There are several reasons for this statement. First, the results are subject to splitting the CRDAs from directorates into smaller groups

in an arbitrary fashion. Second, the CRDAs were from directorates in Wright Laboratory which have since been absorbed piecemeal into the Air Force Research Laboratory.

Though there are limitations related to the specific results obtained in this effort, it is undeniable that the methodology provides a foundation from which decision-makers can choose one alternative over another. This idea is further delineated in the managerial implications section.

Managerial Implications

In his 1994 research, West's primary objective was to determine why Wright Laboratory participated in technology transfer (1994:54). Among the conclusions drawn, West found that technology transfer success was hard to define, technology transfer is difficult to measure in the near and long term, and that no one metric completely measures technology transfer effectiveness. These shortcomings, to a large degree, still exist in 1998 (Guilfoos, 1998A). Braun and Davis have taken strides to define the benefits associated with technology transfer. The methodology introduced and demonstrated in this research effort, in large part, closes the loop by utilizing their findings.

This closure is especially important for two reasons: (1) once again, the goal of technology transfer participation is to maximize ROI on RDT&E (AFMC Handbook, 1995:A-5); and (2) the Stevenson-Wydler Technology Innovation Act of 1980 requires that a minimum of 0.5% an organization's R&D budget is to be spent on activities related to technology transfer (AFMC Handbook, 1995:A-2). This means money is going to be spent and that it is supposed to be spent in the way that provides the largest possible return on investment.

The bottom line is this: the methodology enables decision-makers to use both objective and subjective benefit measurements to determine which CRDAs to enter into. They now have a way to determine the ROI associated with transfer opportunities so that they can make educated decisions as opposed to relying on instinct.

Future Research Recommendations

The benefit of this research effort is that it provides decision-makers with a tool to assess ROI, not specific results on which to make future transfer choices. There are several reasons this comment is necessary. First, the results obtained in Chapter IV are based upon an arbitrary grouping of CRDAs. Second, the CRDAs were from Wright Laboratory (WL) which has since been incorporated into the Air Force Research Laboratory (AFRL). As such, the directorates examined in Chapter IV are now dispersed into different parts of AFRL. Nevertheless, the following are several suggestions for follow-on research:

1. **Expand the Model:** The model illustrated in this research is concerned solely with the benefits experienced by the government in technology transfer. It has been shown in Chapter I that there are nongovernmental benefits such as the stimulation of the economy, etc. These benefits were examined in the AFMC TTO 1994 paper entitled "Technology Transfer: The Payoff/Benefits' Indicator." Using these two research sources as a starting point, both governmental and nongovernmental benefits could be examined and the model broadened.

2. **Sensitivity analysis:** This research effort performed sensitivity analysis by varying the relative importance of objective benefits to subjective benefits (α). Further sensitivity

analysis could be performed by varying the unitized weights (relative importance of subjective benefits to one another).

3. **Other Possibilities:** Other areas of possible follow-on research include applying the methodology to AFRL CRDAs. The collection of non-proprietary data would enable validation of results, which could be accomplished through the comparison of expert opinions to model results. A final option is to apply the procedure to another government organization such as the Department of Energy.

Summary

Air Force technology transfer began in the early 1980's when it was realized that technology transfer could provide benefits such as lower R&D costs to government and commercial industry participants alike. Over the past two decades, many advances to the technology transfer process have been made (e.g., development of CRDAs). This research effort improves the process by introducing a model to determine return on investment. The model considers both the objective and subjective benefits and helps decision-makers choose between potential alternatives. This choice is not limited to comparing benefits as the model's sensitivity analysis capability enables choices to be made based on the decision-maker's perspective concerning each benefit's importance. The model not only fills a current void in technology transfer, it champions transferring those technologies that are most beneficial. The model, together with the opportunities for improvement listed in the future research recommendation's section, will improve the technology transfer process. Technology transfer and its continued improvement are vital as the United States attempts to maintain a technological edge.

Appendix A: CRDA Benefits Questionnaire

Background Information (Print responses):

1. Name/Office Symbol: ______________________________

2. Position Title: ______________________________________

3. CRDA Number: ______________________________________

4. CRDA Title: ____________________________________

Quantitative Benefits (Place x in box for yes or no, Print dollar amounts as appropriate, Include estimates of future benefits that are likely to occur within 2 years or less):

5. **a.** Did the government receive any kind of royalty payments as a direct result of this CRDA?
   ☐ **Yes** ☐ **No**
   b. If yes, estimate the total amount of royalty payments?
   To date: $__________ Future: $__________

6. **a.** Did the government receive any kind of cash reimbursement for services performed by the laboratory as a direct result of this CRDA (e.g., facilities payments or salary payments)?
   ☐ **Yes** ☐ **No**
   b. If yes, estimate the total amount of all cash reimbursements?
   To date: $__________ Future: $__________

7. **a.** Did the government receive any kind of license fees as a direct result of this CRDA?
   ☐ **Yes** ☐ **No**
   b. If yes, estimate the total amount of license fees?
   To date: $__________ Future: $__________

8. **a.** Did the government realize any financial benefits that are not directly payable as cash as a direct result of this CRDA?
   ☐ **Yes** ☐ **No**
   b. If yes, estimate the total amount of cost savings for each category?

Work Avoidance:	To date: $__________	Future: $__________
Data Received:	To date: $__________	Future: $__________
Software Received:	To date: $__________	Future: $__________
Hardware Received:	To date: $__________	Future: $__________
Other _______:	To date: $__________	Future: $__________

Qualitative Benefits (Place x in box for yes or no, If yes then Circle the most appropriate response for each part b):

9. a. Did this CRDA result in productivity increases in the laboratory (e.g., increased automation)?

❑ **Yes** ❑ **No**

b. If yes, then rate the importance of these productivity increases to the laboratory.

1	2	3	4	5
not important	slightly important	moderately important	very important	extremely important

10. a. Did this CRDA result in better utilization of laboratory resources (e.g., more use of a laboratory test facility)?

❑ **Yes** ❑ **No**

b. If yes, then rate the importance of this better utilization of resources to the laboratory.

1	2	3	4	5
not important	slightly important	moderately important	very important	extremely important

11. a. Did this CRDA result in improved management and business practices in the laboratory (e.g., improved skills and techniques through interaction with the partner)?

❑ **Yes** ❑ **No**

b. If yes, then rate the importance of these improved management and business practices to the laboratory.

1	2	3	4	5
not important	slightly important	moderately important	very important	extremely important

12. a. Did this CRDA result in improved laboratory image?

❑ **Yes** ❑ **No**

b. If yes, then rate the importance of this improved laboratory image to the laboratory.

1	2	3	4	5
not important	slightly important	moderately important	very important	extremely important

13. a. Did this CRDA result in improved morale in the laboratory?

❑ **Yes** ❑ **No**

b. If yes, then rate the importance of this improved morale to the laboratory.

1	2	3	4	5
not important	slightly important	moderately important	very important	extremely important

14. a. Did this CRDA result in improved technical capability in the laboratory?

❑ **Yes** ❑ **No**

b. If yes, then rate the importance of this improved technical capability to the laboratory.

1	2	3	4	5
not important	slightly important	moderately important	very important	extremely important

Appendix B: Technology Transfer Return on Investment Questionnaire

Previous research has indicated that technology transfer benefits are both objective and subjective in nature. The purpose of my research is to determine a model that enables one to determine which transfer opportunities (CRDAs) are most desirable. In order to develop a ROI model concerning technology transfer, I need to understand which benefits are most important to decision-makers. The three sections below contain possible benefits associated with a hypothetical CRDA (subjective and objective benefits). Each section contains the definitions for each benefit and then provides an example of how to provide responses indicating the importance you place on each benefit in comparison to each other. Your task is to provide your rating of each benefit in comparison to each other.

SECTION 1 – SUBJECTIVE BENEFITS:

1. Productivity – Did this CRDA result in productivity increases in the laboratory (e.g., is the lab more efficient in its technology development)?

2. Resource utilization – Did this CRDA result in better utilization of specialized laboratory resources (e.g., more use of a laboratory test facility)?

3. Management – Did this CRDA result in improved management and business practices in the laboratory (e.g., improved skills and techniques through interaction with the partner)?

4. Image – Did this CRDA result in improved laboratory image?

5. Morale- Did this CRDA result in improved morale in the laboratory?

6. Technical Capability- Did this CRDA improve lab personnel technical capability?

Given the above definitions, please rate the individual subjective benefits with respect to each other. Specifically, how much (of a possible 100 points) is each subjective benefit of value to you as a manager (NOTE: the 6 values must sum to 100). An example response is provided.

EXAMPLE RESPONSE		**YOUR RESPONSE**	
Productivity	12	**Productivity**	___
Resource utilization	25	**Resource utilization**	___
Management	15	**Management**	___
Image	5	**Image**	___
Morale	20	**Morale**	___
Technical Capability	23	**Technical Capability**	___
TOTAL	**100**	**TOTAL**	**100**

SECTION 2 – OBJECTIVE BENEFITS:

1. Royalties – Did the government receive any kind of royalty payment as a direct result of this CRDA?

2. Cash reimbursement – Did the government receive any kind of cash reimbursement for services performed by the laboratory as a direct result of this CRDA?

2. License fees – Did the government receive any kind of license fees as a direct result of this CRDA?

1. Work avoidance - Did the government realize any financial benefits that are not directly payable as cash as a direct result of this CRDA: specifically work avoidance?

2. Data received - Did the government realize any financial benefits that are not directly payable as cash as a direct result of this CRDA: specifically data received?

3. Software received - Did the government realize any financial benefits that are not directly payable as cash as a direct result of this CRDA: specifically software received?

4. Hardware received - Did the government realize any financial benefits that are not directly payable as cash as a direct result of this CRDA: specifically hardware received?

Given the above definitions, please rate the individual objective benefits with respect to each other. Specifically, how much (of a possible 100 points) is each objective benefit of value to you as a manager (NOTE: the 7 values must sum to 100). An example response is provided.

EXAMPLE RESPONSE		YOUR RESPONSE	
Royalty payments	25	**Royalty payments**	___
Cash reimbursements	25	**Cash reimbursements**	___
License fees	15	**License fees**	___
Work avoidance	15	**Work avoidance**	___
Data received	5	**Data received**	___
Software received	5	**Software received**	___
Hardware received	10	**Hardware received**	___
TOTAL	**100**	**TOTAL**	**100**

SECTION 3 – OBJECTIVE VERSUS SUBJECTIVE BENEFITS:

As a manager, what is your overall impression of the importance of objective versus subjective benefits? The example below shows objective benefits being 3 times more important.

EXAMPLE RESPONSE		YOUR RESPONSE	
Objective benefits	75	**Objective benefits**	___
Subjective benefits	25	**Subjective benefits**	___
TOTAL	**100**	**TOTAL**	**100**

Appendix C: CRDA Worksheets

MATERIALS A CRDAs

OBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 1	CRDA 2	CRDA 3	CRDA 4	CRDA 5	CRDA 6	CRDA 7	CRDA 8	CRDA 9	CRDA 10	CRDA 11	TOTALS
Royalty Payments	$0	$0	$0	$1,000	$5,000	$0	$0	$0	$0	$0	$15,000	$21,000
Cash Reimbursements	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
License Fees	$0	$0	$0	$0	$5,000	$0	$0	$0	$0	$0	$25,000	$30,000
Work Avoidance	$0	$0	$0	$250,000	$0	$0	$0	$0	$10,000	$0	$100,000	$360,000
Data Received	$0	$0	$0	$0	$0	$0	$0	$0	$10,000	$0	$90,000	$100,000
Software Received	$0	$0	$0	$14,000	$0	$0	$0	$0	$0	$0	$0	$14,000
Hardware Received	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
CRDA TOTALS	$0	$0	$0	$265,000	$10,000	$0	$0	$0	$20,000	$0	$230,000	$525,000
OM_k =	**0.0000**	**0.0000**	**0.0000**	**0.5048**	**0.0190**	**0.0000**	**0.0000**	**0.0000**	**0.0381**	**0.0000**	**0.4381**	**1.0000**

SUBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 1	CRDA 2	CRDA 3	CRDA 4	CRDA 5	CRDA 6	CRDA 7	CRDA 8	CRDA 9	CRDA 10	CRDA 11	TOTALS
Productivity	0	0	0	4	0	0	0	0	0	0	4	8
Resource Utilization	3	0	0	4	0	0	0	0	4	0	4	15
Management	0	0	0	0	3	3	3	3	5	0	0	17
Image	5	2	3	3	4	4	4	4	5	3	4	41
Morale	0	0	0	0	4	4	4	4	5	0	4	25
Technical Capability	0	0	0	4	3	0	0	0	5	0	5	17

UNITIZED WEIGHT	BENEFITS	CRDA 1	CRDA 2	CRDA 3	CRDA 4	CRDA 5	CRDA 6	CRDA 7	CRDA 8	CRDA 9	CRDA 10	CRDA 11	TOTALS
0.2450	Productivity	0.0000	0.0000	0.0000	0.5000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5000	1.0000
0.2150	Resource Utilization	0.2000	0.0000	0.0000	0.2667	0.0000	0.0000	0.0000	0.0000	0.2667	0.0000	0.2667	1.0000
0.1250	Management	0.0000	0.0000	0.0000	0.0000	0.1765	0.1765	0.1765	0.1765	0.2941	0.0000	0.0000	1.0000
0.1450	Image	0.1220	0.0488	0.0732	0.0732	0.0976	0.0976	0.0976	0.0976	0.1220	0.0732	0.0976	1.0000
0.0825	Morale	0.0000	0.0000	0.0000	0.0000	0.1600	0.1600	0.1600	0.1600	0.2000	0.0000	0.1600	1.0000
0.1875	Technical Capability	0.0000	0.0000	0.0000	0.2353	0.1765	0.0000	0.0000	0.0000	0.2941	0.0000	0.2941	1.0000
1.0000	**SM_k =**	**0.0607**	**0.0071**	**0.0106**	**0.2346**	**0.0825**	**0.0494**	**0.0494**	**0.0494**	**0.1834**	**0.0106**	**0.2623**	**1.0000**
Alpha = .5625	**WE_k =**	**0.0265**	**0.0031**	**0.0046**	**0.3865**	**0.0468**	**0.0216**	**0.0216**	**0.0216**	**0.1017**	**0.0046**	**0.3612**	**1.0000**

MATERIALS B CRDAs

OBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 12	CRDA 13	CRDA 14	CRDA 15	CRDA 16	CRDA 17	CRDA 18	CRDA 19	CRDA 20	CRDA 21	TOTALS
Royalty Payments	$50,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$50,000
Cash Reimbursements	$0	$0	$100,000	$0	$0	$0	$26,060	$0	$0	$0	$126,060
License Fees	$0	$0	$0	$0	$400	$0	$0	$0	$0	$0	$400
Work Avoidance	$75,000	$125,000	$0	$100,000	$7,000	$0	$0	$0	$0	$0	$307,000
Data Received	$10,000	$100,000	$0	$0	$0	$0	$15,000	$0	$50,000	$50,000	$225,000
Software Received	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Hardware Received	$0	$0	$0	$0	$100,000	$0	$0	$0	$0	$0	$100,000
CRDA TOTALS	$135,000	$225,000	$100,000	$100,000	$107,400	$0	$41,060	$0	$50,000	$50,000	$808,460
OM_k =	**0.1670**	**0.2783**	**0.1237**	**0.1237**	**0.1328**	**0.0000**	**0.0508**	**0.0000**	**0.0618**	**0.0618**	**1.0000**

SUBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 12	CRDA 13	CRDA 14	CRDA 15	CRDA 16	CRDA 17	CRDA 18	CRDA 19	CRDA 20	CRDA 21	TOTALS
Productivity	4	4	0	3	3	0	0	0	0	0	14
Resource Utilization	5	5	4	0	0	0	0	0	3	3	20
Management	0	0	4	3	5	0	0	0	0	0	12
Image	5	4	4	5	3	0	3	0	3	3	30
Morale	4	4	4	3	5	0	3	0	0	0	23
Technical Capability	4	4	0	0	0	0	0	0	2	3	13

UNITIZED WEIGHT	BENEFITS	CRDA 12	CRDA 13	CRDA 14	CRDA 15	CRDA 16	CRDA 17	CRDA 18	CRDA 19	CRDA 20	CRDA 21	TOTALS
0.2450	Productivity	0.2857	0.2857	0.0000	0.2143	0.2143	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.2150	Resource Utilization	0.2500	0.2500	0.2000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1500	0.1500	1.0000
0.1250	Management	0.0000	0.0000	0.3333	0.2500	0.4167	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.1450	Image	0.1667	0.1333	0.1333	0.1667	0.1000	0.0000	0.1000	0.0000	0.1000	0.1000	1.0000
0.0825	Morale	0.1739	0.1739	0.1739	0.1304	0.2174	0.0000	0.1304	0.0000	0.0000	0.0000	1.0000
0.1875	Technical Capability	0.3077	0.3077	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1538	0.2308	1.0000
1.0000	**SM_k =**	**0.2200**	**0.2151**	**0.1183**	**0.1187**	**0.1370**	**0.0000**	**0.0253**	**0.0000**	**0.0756**	**0.0900**	**1.0000**
Alpha = .5625	**WE_k =**	**0.1902**	**0.2507**	**0.1214**	**0.1215**	**0.1347**	**0.0000**	**0.0396**	**0.0000**	**0.0679**	**0.0742**	**1.0000**

MATERIALS C CRDAs

OBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 22	CRDA 23	CRDA 24	CRDA 25	CRDA 26	CRDA 27	CRDA 28	CRDA 29	CRDA 30	CRDA 31	TOTALS
Royalty Payments	$0	$0	$0	$1,000	$5,000	$0	$0	$0	$0	$0	$6,000
Cash Reimbursements	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
License Fees	$0	$0	$0	$0	$5,000	$0	$0	$0	$0	$0	$5,000
Work Avoidance	$0	$0	$0	$250,000	$0	$0	$0	$0	$10,000	$0	$260,000
Data Received	$0	$0	$0	$0	$0	$0	$0	$0	$10,000	$0	$10,000
Software Received	$0	$0	$0	$14,000	$0	$0	$0	$0	$0	$0	$14,000
Hardware Received	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
CRDA TOTALS	$0	$0	$0	$265,000	$10,000	$0	$0	$0	$20,000	$0	$295,000
OM_k =	**0.0000**	**0.0000**	**0.0000**	**0.8983**	**0.0339**	**0.0000**	**0.0000**	**0.0000**	**0.0678**	**0.0000**	**1.0000**

SUBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 22	CRDA 23	CRDA 24	CRDA 25	CRDA 26	CRDA 27	CRDA 28	CRDA 29	CRDA 30	CRDA 31	TOTALS
Productivity	0	0	0	4	0	0	0	0	0	0	4
Resource Utilization	3	0	0	4	0	0	0	0	4	0	11
Management	0	0	0	0	3	3	3	3	5	0	17
Image	5	2	3	3	4	4	4	4	5	3	37
Morale	0	0	0	0	4	4	4	4	5	0	21
Technical Capability	0	0	0	4	3	0	0	0	5	0	12

UNITIZED WEIGHT	BENEFITS	CRDA 22	CRDA 23	CRDA 24	CRDA 25	CRDA 26	CRDA 27	CRDA 28	CRDA 29	CRDA 30	CRDA 31	TOTALS
0.2450	Productivity	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.2150	Resource Utilization	0.2727	0.0000	0.0000	0.3636	0.0000	0.0000	0.0000	0.0000	0.3636	0.0000	1.0000
0.1250	Management	0.0000	0.0000	0.0000	0.0000	0.1765	0.1765	0.1765	0.1765	0.2941	0.0000	1.0000
0.1450	Image	0.1351	0.0541	0.0811	0.0811	0.1081	0.1081	0.1081	0.1081	0.1351	0.0811	1.0000
0.0825	Morale	0.0000	0.0000	0.0000	0.0000	0.1905	0.1905	0.1905	0.1905	0.2381	0.0000	1.0000
0.1875	Technical Capability	0.0000	0.0000	0.0000	0.3333	0.2500	0.0000	0.0000	0.0000	0.4167	0.0000	1.0000
1.0000	**SM_k =**	**0.0782**	**0.0078**	**0.0118**	**0.3974**	**0.1003**	**0.0534**	**0.0534**	**0.0534**	**0.2323**	**0.0118**	**1.0000**
Alpha = .5625	**WE_k =**	**0.0342**	**0.0034**	**0.0051**	**0.6792**	**0.0630**	**0.0234**	**0.0234**	**0.0234**	**0.1398**	**0.0051**	**1.0000**

FLIGHT DYNAMICS A CRDAs

OBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 1	CRDA 2	CRDA 3	CRDA 4	CRDA 5	CRDA 6	CRDA 7	CRDA 8	TOTALS
Royalty Payments	$0	$0	$74,000	$0	$0	$0	$0	$5,000	$79,000
Cash Reimbursements	$0	$0	$0	$0	$0	$0	$0	$0	$0
License Fees	$0	$0	$0	$0	$0	$0	$0	$0	$0
Work Avoidance	$590,000	$0	$1,200,000	$0	$0	$0	$0	$0	$1,790,000
Data Received	$10,000	$0	$0	$0	$0	$0	$0	$0	$10,000
Software Received	$0	$0	$120,000	$0	$0	$0	$0	$5,000	$125,000
Hardware Received	$0	$0	$0	$0	$0	$0	$0	$0	$0
CRDA TOTALS	$600,000	$0	$1,394,000	$0	$0	$0	$0	$10,000	$2,004,000
OM_k =	**0.2994**	**0.0000**	**0.6956**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0050**	**1.0000**

SUBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 1	CRDA 2	CRDA 3	CRDA 4	CRDA 5	CRDA 6	CRDA 7	CRDA 8	TOTALS
Productivity	0	0	4	0	0	0	0	2	6
Resource Utilization	3	4	4	0	0	0	0	2	13
Management	4	3	4	0	0	0	0	0	11
Image	4	5	4	0	0	3	0	2	18
Morale	2	4	3	0	0	2	0	0	11
Technical Capability	4	5	5	0	0	3	0	3	20

UNITIZED WEIGHT	BENEFITS	CRDA 1	CRDA 2	CRDA 3	CRDA 4	CRDA 5	CRDA 6	CRDA 7	CRDA 8	TOTALS
0.2450	Productivity	0.0000	0.0000	0.6667	0.0000	0.0000	0.0000	0.0000	0.3333	1.0000
0.2150	Resource Utilization	0.2308	0.3077	0.3077	0.0000	0.0000	0.0000	0.0000	0.1538	1.0000
0.1250	Management	0.3636	0.2727	0.3636	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.1450	Image	0.2222	0.2778	0.2222	0.0000	0.0000	0.1667	0.0000	0.1111	1.0000
0.0825	Morale	0.1818	0.3636	0.2727	0.0000	0.0000	0.1818	0.0000	0.0000	1.0000
0.1875	Technical Capability	0.2000	0.2500	0.2500	0.0000	0.0000	0.1500	0.0000	0.1500	1.0000
1.0000	**SM_k =**	**0.1798**	**0.2174**	**0.3765**	**0.0000**	**0.0000**	**0.0673**	**0.0000**	**0.1590**	**1.0000**
Alpha = .5625	**WE_k =**	**0.2471**	**0.0951**	**0.5560**	**0.0000**	**0.0000**	**0.0294**	**0.0000**	**0.0724**	**1.0000**

FLIGHT DYNAMICS B CRDAs

OBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 9	CRDA 10	CRDA 11	CRDA 12	CRDA 13	CRDA 14	CRDA 15	CRDA 16	TOTALS
Royalty Payments	$0	$0	$25,500	$0	$0	$0	$0	$0	$25,500
Cash Reimbursements	$0	$0	$0	$0	$0	$3,000	$0	$5,000	$8,000
License Fees	$0	$0	$0	$0	$0	$0	$0	$0	$0
Work Avoidance	$0	$0	$0	$0	$0	$0	$0	$0	$0
Data Received	$0	$0	$0	$0	$0	$0	$0	$0	$0
Software Received	$0	$0	$0	$0	$0	$0	$0	$0	$0
Hardware Received	$0	$0	$0	$0	$0	$0	$0	$0	$0
CRDA TOTALS	$0	$0	$25,500	$0	$0	$3,000	$0	$5,000	$33,500
OM_k =	**0.0000**	**0.0000**	**0.7612**	**0.0000**	**0.0000**	**0.0896**	**0.0000**	**0.1493**	**1.0000**

SUBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 9	CRDA 10	CRDA 11	CRDA 12	CRDA 13	CRDA 14	CRDA 15	CRDA 16	TOTALS
Productivity	0	0	0	0	0	3	2	4	9
Resource Utilization	0	0	0	0	3	0	0	3	6
Management	2	0	4	0	3	0	0	0	9
Image	0	0	4	0	4	0	3	3	14
Morale	0	5	5	0	4	0	0	3	17
Technical Capability	2	0	0	0	0	2	0	4	8

UNITIZED WEIGHT	BENEFITS	CRDA 9	CRDA 10	CRDA 11	CRDA 12	CRDA 13	CRDA 14	CRDA 15	CRDA 16	TOTALS
0.2450	Productivity	0.0000	0.0000	0.0000	0.0000	0.0000	0.3333	0.2222	0.4444	1.0000
0.2150	Resource Utilization	0.0000	0.0000	0.0000	0.0000	0.5000	0.0000	0.0000	0.5000	1.0000
0.1250	Management	0.2222	0.0000	0.4444	0.0000	0.3333	0.0000	0.0000	0.0000	1.0000
0.1450	Image	0.0000	0.0000	0.2857	0.0000	0.2857	0.0000	0.2143	0.2143	1.0000
0.0825	Morale	0.0000	0.2941	0.2941	0.0000	0.2353	0.0000	0.0000	0.1765	1.0000
0.1875	Technical Capability	0.2500	0.0000	0.0000	0.0000	0.0000	0.2500	0.0000	0.5000	1.0000
1.0000	**SM_k =**	**0.0747**	**0.0243**	**0.1212**	**0.0000**	**0.2100**	**0.1285**	**0.0855**	**0.3558**	**1.0000**
Alpha = .5625	**WE_k =**	**0.0327**	**0.0106**	**0.4812**	**0.0000**	**0.0919**	**0.1066**	**0.0374**	**0.2396**	**1.0000**

PROPULSION CRDAs

OBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 1	CRDA 2	CRDA 3	CRDA 4	CRDA 5	CRDA 6	CRDA 7	CRDA 8	CRDA 9	TOTALS
Royalty Payments	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Cash Reimbursements	$2,000,000	$0	$0	$0	$197,495	$0	$0	$0	$660,000	$2,857,495
License Fees	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Work Avoidance	$0	$0	$0	$70,000	$0	$0	$0	$0	$0	$70,000
Data Received	$0	$0	$0	$0	$210,000,000	$0	$0	$40,000	$0	$210,040,000
Software Received	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Hardware Received	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
CRDA TOTALS	$2,000,000	$0	$0	$70,000	$210,197,495	$0	$0	$40,000	$660,000	$212,967,495
OM_k =	**0.0094**	**0.0000**	**0.0000**	**0.0003**	**0.9870**	**0.0000**	**0.0000**	**0.0002**	**0.0031**	**1.0000**

SUBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 1	CRDA 2	CRDA 3	CRDA 4	CRDA 5	CRDA 6	CRDA 7	CRDA 8	CRDA 9	TOTALS
Productivity	0	0	0	0	0	3	0	0	0	3
Resource Utilization	4	0	3	3	0	3	3	3	4	23
Management	4	0	2	0	3	3	3	0	0	15
Image	4	0	0	5	0	3	3	0	3	18
Morale	3	0	2	0	2	3	0	0	0	10
Technical Capability	4	0	2	4	0	3	3	0	3	19

UNITIZED WEIGHT	BENEFITS	CRDA 1	CRDA 2	CRDA 3	CRDA 4	CRDA 5	CRDA 6	CRDA 7	CRDA 8	CRDA 9	TOTALS
0.2450	Productivity	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	1.0000
0.2150	Resource Utilization	0.1739	0.0000	0.1304	0.1304	0.0000	0.1304	0.1304	0.1304	0.1739	1.0000
0.1250	Management	0.2667	0.0000	0.1333	0.0000	0.2000	0.2000	0.2000	0.0000	0.0000	1.0000
0.1450	Image	0.2222	0.0000	0.0000	0.2778	0.0000	0.1667	0.1667	0.0000	0.1667	1.0000
0.0825	Morale	0.3000	0.0000	0.2000	0.0000	0.2000	0.3000	0.0000	0.0000	0.0000	1.0000
0.1875	Technical Capability	0.2105	0.0000	0.1053	0.2105	0.0000	0.1579	0.1579	0.0000	0.1579	1.0000
1.0000	**SM_k =**	**0.1672**	**0.0000**	**0.0809**	**0.1078**	**0.0416**	**0.3766**	**0.1068**	**0.0280**	**0.0912**	**1.0000**
Alpha = .5625	**WE_k =**	**0.0784**	**0.0000**	**0.0354**	**0.0473**	**0.5733**	**0.1647**	**0.0467**	**0.0124**	**0.0416**	**1.0000**

AVIONICS CRDAs

OBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 1	CRDA 2	CRDA 3	CRDA 4	CRDA 5	CRDA 6	CRDA 7	CRDA 8	CRDA 9	TOTALS
Royalty Payments	$0	$0	$0	$20,000	$0	$0	$0	$0	$0	$20,000
Cash Reimbursements	$0	$0	$0	$0	$0	$0	$20,000	$0	$200,000	$220,000
License Fees	$0	$0	$0	$0	$0	$0	$0	$0	$10,000	$10,000
Work Avoidance	$100,000	$40,000	$0	$0	$0	$0	$0	$50,000	$0	$190,000
Data Received	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Software Received	$0	$20,000	$0	$0	$12,000	$0	$0	$0	$0	$32,000
Hardware Received	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
CRDA TOTALS	$100,000	$60,000	$0	$20,000	$12,000	$0	$20,000	$50,000	$210,000	$472,000
OM_k =	0.2119	0.1271	0.0000	0.0424	0.0254	0.0000	0.0424	0.1059	0.4449	1.0000

SUBJECTIVE MEASUREMENTS:

BENEFITS	CRDA 1	CRDA 2	CRDA 3	CRDA 4	CRDA 5	CRDA 6	CRDA 7	CRDA 8	CRDA 9	TOTALS
Productivity	0	3	0	0	4	0	0	0	0	7
Resource Utilization	0	3	3	0	4	0	0	0	0	10
Management	0	0	0	3	2	0	0	0	0	5
Image	2	2	3	4	2	0	0	0	3	16
Morale	0	0	3	3	3	0	0	0	0	9
Technical Capability	4	2	3	4	4	0	0	0	0	17

UNITIZED WEIGHT	BENEFITS	CRDA 1	CRDA 2	CRDA 3	CRDA 4	CRDA 5	CRDA 6	CRDA 7	CRDA 8	CRDA 9	TOTALS
0.2450	Productivity	0.0000	0.4286	0.0000	0.0000	0.5714	0.0000	0.0000	0.0000	0.0000	1.0000
0.2150	Resource Utilization	0.0000	0.3000	0.3000	0.0000	0.4000	0.0000	0.0000	0.0000	0.0000	1.0000
0.1250	Management	0.0000	0.0000	0.0000	0.6000	0.4000	0.0000	0.0000	0.0000	0.0000	1.0000
0.1450	Image	0.1250	0.1250	0.1875	0.2500	0.1250	0.0000	0.0000	0.0000	0.1875	1.0000
0.0825	Morale	0.0000	0.0000	0.3333	0.3333	0.3333	0.0000	0.0000	0.0000	0.0000	1.0000
0.1875	Technical Capability	0.2353	0.1176	0.1765	0.2353	0.2353	0.0000	0.0000	0.0000	0.0000	1.0000
1.0000	SM_k =	0.0622	0.2097	0.1523	0.1829	0.3657	0.0000	0.0000	0.0000	0.0272	1.0000
Alpha = .5625	WE_k =	0.1464	0.1632	0.0666	0.1038	0.1743	0.0000	0.0238	0.0596	0.2622	1.0000

References

Air Force Material Command (AFMC). AFMC Technology Transfer Handbook. Wright-Patterson AFB OH, November 1995.

Air Force Material Command Technology Transfer Office (AFMC/TTO). "Technology Transfer: The 'Payoff/Benefits' Indicator," Unpublished Paper, 20 October 1994.

Baron, Seymour. "Overcoming Barriers to Technology Transfer," Research Technology Management, 38-43, January-February 1990.

Boyd, James C. III. Identifying Cost Patterns of Managing Technology Transfer Actions. MS Thesis, AFIT/GSM/LAS/96S-2, Graduate School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1996 (AD-A319490).

Braun, Clinton J. An Exploratory Study of the Benefits Received by Wright Laboratory (WL) From Technology Transfer Activities. MS Thesis, AFIT/GCA/LAS/96S-1, Graduate School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1996 (AD-A320969).

Burnett, William M., Dominic J. Monetta and Barry G. Silverman. "How the Gas Research Institute (GRI) Helped Transform the US Natural Gas Industry," Interfaces, 44-58, (January-February, 1993).

Burnett, William M., Barry G. Silverman and Dominic J. Monetta. "R&D Project Appraisal at the Gas Research Institute: Part II," Operations Research, 1020-1032 (November-December, 1993).

Canada, John R. and William G. Sullivan. Economic and Multiattribute Evaluation of Advanced Manufacturing Systems. New Jersey: Prentice Hall, 1989.

Carr, Robert K. "Doing Technology Transfer in Federal Laboratories (Part 1)," Journal of Technology Transfer, 17, 8-23, (Spring-Summer 1992A).

Carr, Robert K. "Menu of Best Practices in Technology Transfer (Part 2)," Journal of Technology Transfer, 17, 24-33, (Spring-Summer 1992B).

Carter, William K. "To Invest in New Technology or Not? New Tools for Making the Decision," Journal of Accountancy, 58-64 (May 1992).

Clinton, William and Albert Gore, Jr. "Technology for America's Economic Growth, A New Direction to Build Economic Strength," Washington DC, 22 February 1993.

Davis, Mark J. Relationships Between CRDA Elements and Benefits to the Government in Technology Transfer. MS Thesis, AFIT/GSM/LAS/97S-1, Graduate School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1997 (AD-A329840).

Duga, Jules. "The Case for a Federal Role in Technology Transfer: The Environment of Change in Technology Acquisition," Technology Exchange, 4-11 (1998).

Gottinger, Hans W. "Social Cost and Benefits Associated With the Industry Development Process for SDI-Related Spin-Off Technologies," International Journal of Technology Management, 685-702 (1990).

Guilfoos, Stephen J. Air Force Program Manager, Air Force Technology Transfer Program, AFRL/XPTT. Personal Interview. 15 April 1998A.

Guilfoos, Stephen J. Cooperative Research and Development Agreement (CRDA) Excel spreadsheet. 2 Feb 1998B.

Guilfoos, Stephen J. "Concept of Operations for the AFRL Technology Transfer Programs". Report to AFRL/CC. 25 Mar 1998C.

Horngren, Charles T., George Foster and Srikant M. Datar. Cost Accounting – A Managerial Emphasis (Ninth Edition). New Jersey: Prentice Hall, 1997

Knauth, Kristin. "Sharing the Technological Wealth," Government Executive, 33-38 (November 1991).

Papadakis, Maria. "Federal Laboratory Missions, Products, and Competitiveness," Journal of Technology Transfer, 54-66 (April 1995).

Roessner, David J. "What Companies Want From the Federal Labs," Issues in Science and Technology, 36-42 (Fall 1993).

Schroer, Bernard J. and others. "Measuring Technology Transfer Performance: A Case Study," Journal of Technology Transfer, 39-47 (September 1995).

Scott, William B. "U.S. Labs Embrace Technology Transfer," Aviation Week & Space Technology, 64-66, (August 23, 1993).

Souder, William E., Ahmed S. Nashar and Venkatesh Padmanabhan. "A Guide to the Best Technology Transfer Practices," Journal of Technology Transfer, 5-13 (Winter-Spring 1990).

Spann, Mary S., Mel Adams and William E. Souder. "Measures of Technology Transfer Effectiveness: Key Dimensions and Differences in Their Use by Sponsors, Developers, and Adopters," IEEE Transactions on Engineering Management, 42, 19-29 (February 1995).

Strategic Development Staff. Focus. Ann Arbor MI: National Center for Manufacturing Sciences Incorporated, 1, 8 (January 1992).

Studt, Tim and Jules Duga. "Increased R&D is Tied to Long-term Economic Growth," R&D Magazine, 1-7 (January 1997).

Van Egeren, Thomas S. Tracking Overhead ORTA Costs in Technology Transfer Activities. MS Thesis, AFIT/GCA/LAS/97S-9, Graduate School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1997 (AD-A329941).

Weijo, Richard O. "Strategies for Promoting Technology Transfer to the Private Sector." Journal of Technology Transfer, 43-65 (Summer 1987).

West, William K. An Exploration of Technology Transfer Control: A Case Study of Wright Laboratory. MS Thesis, AFIT/GSM/LAS/94D-1, Graduate School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1994 (AD-A288876).

Willett, Hugh. "How Linear Technology Gets the Biggest Bang for its R&D Bucks," Electronic Business, 96-102 (August 1992).

Winebrake, James J. "A Study of Technology Transfer Mechanisms for Federally Funded R&D," Journal of Technology Transfer, 54-61 (Fall 1992).

Wright-Patterson Air Force Base. "Wright-Patterson Legacy." 1995.

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13. ABSTRACT *(Maximum 200 Words)*
Air Force policy states the fundamental reason for participating in technology transfer is to maximize the return on investment (ROI) on research and development (R&D) funds. Public law dictates that federal agencies, including the Air Force, are to spend no less than 0.5% of their overall R&D budget in the pursuit of technology transfer. However, there is currently no ROI model available to the decision-maker in the evaluation of alternative transfer opportunities. This research effort develops a model that measures the ROI of individual cooperative research and development agreements (CRDAs) on the basis of the objective and subjective benefits amassed. The model results assist the decision-maker by providing a relative ranking of each transfer opportunity in comparison to one another. A sensitivity analysis method and results are included which identify definite regions of alternate "optimal" choices depending on the weight given to objective and subjective benefits. Consequently, the decision-maker is provided with a flexible model for use in maximizing ROI, the Air Force's goal for technology transfer.

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